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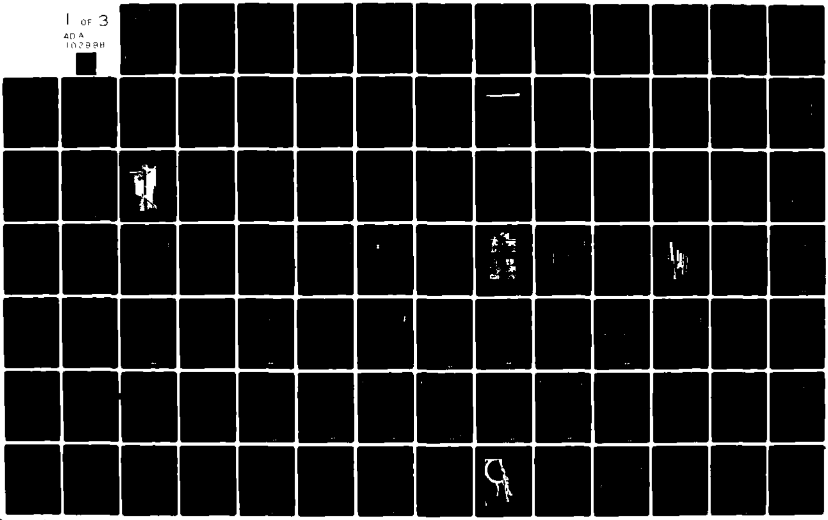

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NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California

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NEARSHORE PIPELINE INSTALLATION METHODS

August 1981

An Investigation Conducted by
DMJM
Pipeline and Marine Division
Houston, Texas

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The primary purpose of the study is to provide the Naval Civil Engineering Laboratory with recommendations for existing or new construction methods which are: (1) within present UCT/NMCB capabilities and are the most resource efficient, (2) state-of-the-art methods which are practical for the UCT/NMCB but currently beyond their capabilities due to the team's lack of technological or equipment resources, and (3) not state-of-the-

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art but which have potential for providing a more resource efficient method for use by the UCT/NMCB. Information for the study comes from: a thorough literature search and review, in-house expertise and evaluation, and communications with qualified experts in the fields of marine pipeline construction, with material vendors and manufacturers, and with engineering and construction consultants.

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CHAPTER 1

INTRODUCTION

1.0 GENERAL

This report was prepared for the Civil Engineering Laboratory (CEL), Naval Construction Battalion Center, Port Hueneme, California. It presents the results of a study by Daniel, Mann, Johnson, and Mendenhall (DMJM) to evaluate current state-of-the-art marine pipeline installation methods, potential new installation methods, and the capabilities and limitations of the Underwater Construction Teams and Naval Mobile Construction Battalions (UCT/NMCB) for accomplishing nearshore marine pipeline installations. As the study is limited to nearshore construction methods extending from an onshore location to an offshore location, it is titled "NEARSHORE PIPELINE INSTALLATION METHODS". The primary purpose of the study is to provide the Civil Engineering Laboratory with recommendations for existing or new construction methods which are: (1) within the Seabees' present capabilities and are the most resource efficient; (2) state-of-the-art methods which are practical for the UCT/NMCB but currently beyond their capabilities due to the teams' lack of technological or equipment resources; and (3) not state-of-the-art but which have potential for providing a more resource efficient method for use by the UCT/NMCB. Information for the study came from a thorough literature search and review, in-house expertise and evaluation, communications with qualified experts in the fields of marine pipeline construction, material vendors and manufacturers, and engineering and construction consultants.

On occasion, the Seabees are required to install nearshore pipelines for reasons of security, location, and/or cost. Several nearshore marine pipelines have been successfully installed. Underwater construction on these past projects was performed by the Underwater Construction Teams. Each UCT consists of approximately 35 men with construction trade skills and diving experience. As there are no existing specific guidelines for designing and installing nearshore pipelines, each of these past projects has been a one-of-a-kind effort. The Civil Engineering Laboratory initiated this study realizing that proper evaluation and planning would result in better designed facilities and a more optimum use of manpower, materials, and equipment.

A thorough review of available literature was an initial step in the study development. Appendix A contains a list of pertinent literature. Interviews with industry sources, outside and in-house experts, and material suppliers and manufacturers supplemented the information available to the DMJM study team. From the literature search and interviews, numerous state-of-the-art and conceptual methods were identified. These methods were evaluated in light of the study guidelines,

objectives, and the UCT/NMCB capabilities. Many construction methods did not fit the study scope or objectives. These are briefly discussed along with the reasons for not considering them in detail.

Conclusions and recommendations are summarized in Chapter 2 and are based on detailed discussions presented in other chapters. Chapter 3 discusses the basis of the study and the assumptions and guidelines used in the evaluations. Chapter 4 presents a general discussion of the elements included in a nearshore marine pipeline installation project. The installation classification system developed is presented in Chapter 5. Chapters 6 and 7 discuss state-of-the-art installation methods, and Chapter 8 discusses potential new methods of construction.

CHAPTER 2

CONCLUSIONS AND RECOMMENDATIONS

2.0 CONCLUSIONS

After assessing the UCT/NMCB equipment, personnel, and capabilities, it has been concluded that the upper limit of the 4 inch to 24 inch pipe diameter range is beyond the capabilities of the UCT/NMCB in most instances. A more realistic size range is 4 inch to 12 inch diameter.

Coated steel pipe provides the widest range of utilization but requires qualified welders for joining. Flexible pipe or hose has a high potential for improving resource efficiency when coupled with a reel concept for installation. Plastic pipe is very resource efficient due to the relatively non-technical joining methods required and its light weight.

State-of-the-art methods which are within the present capabilities of the UCT/NMCB units in order of preference are:

a) Pull Method (particularly for pressure lines to be installed in a area with an adequate onshore staging area).
b) Reel Method (limited to small flexible lines).
c) Float, Sink, and Connect (excellent for gravity flow lines).
d) Trestle Method (limited to special cases).

State-of-the-art methods which are <u>not</u> within the present capabilities of the UCT/NMCB unit are:

a) Lay Barge.
b) Reel Method (larger pipe and more sophisticated reel units).
c) Directional Drilling.
d) Float, Connect, and Sink.
e) Jack-Up Platform.

Methods which are state-of-the-art and <u>not</u> within the UCT/NMCB capabilities but which have potential for a significant increase in resource efficiency are:

a) Reel Method (larger pipe and more sophisticated reel units).
b) Modified Lay Barge (using Flexifloats or equivalent).
c) Small Jack-Up Platform (using Flexifloats or equivalent).

The extreme range of shore site conditions, nearshore sea conditions, seabed compositions, and topographies that may be experienced from one site to the next make it impractical for the UCT/NMCB to use only one installation method until further capability is added.

2.1 RECOMMENDATIONS

Other conclusions reached during this study are:

a) None of the completely new methods considered have enough potential for added resource efficiency to justify a major development effort for the study conditions, (i.e. nearshore, shallow water, small diameter lines).
b) New methods considered would provide little improvement over state-of-the-art methods for the study conditions.
c) Some elements identified in the analysis of new methods would improve the teams' resource efficiency, such as improved, simplified couplings, self-contained reel design, and improved hose design.

If site conditions preclude the Pull Method then the Float, Sink, and Connect Method should receive consideration as being the next construction method to be considered by the UCT.

Upon completion of the design phase an outline of the material requirements and installation steps would facilitate implementation of the project construction. Various construction aids would facilitate this. These aids are:

a) Seabed pipe alignment frame for use with the Float, Sink, and Connect Method.
b) Facilities required to install small plastic lines using the modified pull concept explained in Reference No. 91, Appendix A. The concept used steel cable for stability and the pipe was pulled along the pre-installed cable. This was an Air Force project at Eniwetok Atoll.

Additional capabilities which should be added to the UCT/NMCB include:

a) Pipeline welders.
b) Flexifloat units or equivalent to form a nearshore lay barge, jack-up platform, or pull barge.

Recommended research and development includes:

a) Assist suppliers in developing a flexible, medium pressure (200 pounds per square inch gage-psig) hose or pipe which can be spooled on reels.
b) Assist manufacturers of Betalloy couplings to expand pipe diameter capability to 12 inches.
c) Initiate study and development of buoyant sleds or wheels which could be used to support a pipeline being pulled into place and act as anchors for stability after installation.
d) Initiate study and development of compact, self-contained reel unit for use with flexible, medium pressure hose or pipe.

CHAPTER 3

BASIS OF STUDY

3.0 GENERAL

Prior to performing any detailed study it is necessary to establish the basis to be used for evaluation, including assumptions and limiting criteria. Several criteria were specified in the project instructions and scope definitions by the Civil Engineering Laboratory. The initial project meetings and DMJM discussions produced additional constraints and criteria which were considered. This section of the report lists these criteria and assumptions.

3.1 DEFINITIONS OF "INSTALLATION" AND "NEARSHORE"

"Installation" is defined as including the following activities:

a) Mobilization (construction materials, equipment, and personnel).
b) Site preparation (onshore and offshore).
c) Pipe string fabrication (joining).
d) Pipe installation (trench/lay and stabilize/backfill).
e) Logistic support.
f) Inspection and testing.
g) Site restoration.
h) Demobilization.

In practice, installation may or may not include tie-ins at each end of the pipeline or intermediate points. For the purposes of this study installation will not include tie-ins and they have not been specifically addressed in the report.

Installation also includes the joining of pipe and the stabilization of the in-place pipeline. Both joining and stabilization are separate technologies which depend on pipe materials and specific site conditions. These two specialized elements will be considered and discussed only to the extent that they influence a given pipeline installation method.

"Nearshore" is defined to be the zone extending seaward from the shoreline well beyond the breaker zone. This depends on the specific location and environmental conditions of the project and will change from time to time. For this study a nominal distance of two miles was established as the maximum length for pipelines classified as nearshore installations. This two mile distance includes, in all cases, the surf zone and other phenomenon normally associated with nearshore conditions. Water depths rarely exceed 130 feet in this two mile zone. This was based on an analysis of coastal zones of the Atlantic, Gulf of Mexico, and Pacific areas of the Continental United States and the Hawaiian Islands-areas which are considered generally ice-free. An in-depth discussion of these coastlines is included in Appendix B entitled Nearshore Zone - Distance From Shoreline.

3.2 SITE CONDITIONS

The Statement of Work states that all site conditions which exist along the U.S. coastlines (except Alaska) should be considered in this report. Normally this would include extremes of soft mud deposits near river mouths, solid rock bottoms with vertical rock cliffs at the shoreline, and all intermediate conditions. In practice it is doubtful that a design team would locate a pipeline facility at or near the extremes. It is more likely that a site would be chosen which had a gentle shore approach and a shoreline which allowed normal construction activity. For the purpose of installation method evaluation it is assumed that the extremes would be avoided.

Seabed materials have more influence on the method of obtaining on-bottom stability than on the installation method. For instance, rough and uneven seabeds cause spans of unsupported pipe which are subjected to bending stresses and forces induced by currents regardless of the installation method used. Appendix C entitled Site Scenarios presents the development of typical construction site conditions and characteristics. Methods evaluation in Chapters 6 and 7 mention site conditions only if they significantly influence the method.

3.3 PIPELINE PARAMETERS

Another aspect of establishing a basis for this study is developing criteria for the pipeline. These criteria include the physical parameters of the pipe, the operating parameters of the pipeline, the location of the pipeline with respect to the seabed, and the effects of oceanographic conditions on the pipeline.

The following is a summary of the pipeline parameters. Subsequent paragraphs present additional comments on these items:

a) Pipe, size range	4 to 24 inches
b) Pipe, materials of construction:	fully rigid, semi-rigid, flexible
c) Pipeline length, maximum	2 miles
d) Pipeline design life, minimum	15 years
e) Pipeline fluids	liquids - non-corrosive
f) Pipeline temperature, maximum	150 degrees Fahrenheit (°F)
g) Pipeline temperature, minimum	40 (°F)
h) Pipeline pressure, maximum	150 psig
i) Pipeline pressure, minimum	0 psig
j) Pipeline installation:	above seabed, on seabed, below seabed
k) Water depth, maximum	130 feet

The pipe size range of 4 to 24 inches is specified in the Statement of Work. Installation methods requiring specific pipe materials may be limited by the available pipe sizes. These methods were not rejected from consideration but the limitation is here noted. The Statement of Work requires consideration of pipe materials generally categorized as fully rigid (such as steel and reinforced concrete), semi-rigid (such as polyvinyl chloride and high density polyethylene), and flexible (such as Coflexip and hose). These specific categories are discussed in detail in a later section on pipe materials.

The temperature of the pipeline fluid is assumed to range between 40°F to 150°F. This allows considerable latitude for pipeline location, the variety of fluids to be handled, and seasonal temperature variations. One hundred fifty degrees is taken to be a maximum temperature. Petroleum products that would be commonly handled by the UCT/NMCB would tend to vaporize or "flash" before 150°F is reached. Operating temperatures of most conventional onshore pipelines is less than 100°F. Most offshore transporation via pipelines and tanker vessels occurs at or near the ambient temperature of the sea which is generally from 40°F to 65°F.

An operating pressure range of 0 psig to 150 psig is assumed. This encompasses gravity flow lines and medium pressure facilities for fluid transfer. Emphasis is placed on pressure facilities as being more applicable than gravity lines. The pipeline fluids are assumed to be liquids rather than gases or slurries. Liquids are further assumed to be light to heavy fuels, lubricating oils, water, and wastewater. No highly corrosive or toxic liquids are considered as these liquids would not normally be handled by the military nor common to their operations.

Permanent facilities are specified in the Statement of Work. Therefore, a minimum design life of 15 years is chosen, which is nominal for the petro-chemical industry. This is a minimum time, and the length of time that a facility remains in good operating condition is a function of the maintenance program.

Pipeline installations which are considered are those where the pipeline is constructed above, on, or below the existing seabed. This excludes instances where the pipeline is buoyed to float on the surface. It is considered impractical to view a floating installation through a nearshore zone as a permanent facility . In addition to the inherent design problems and questionable practicality of a surface floating pipeline, it would interfere with the flow of marine traffic.

A maximum water depth of 130 feet is specified by the CEL. At this depth self contained underwater breathing apparatus (SCUBA) or full face (hat) diving on air is not a particular problem although decompression is required for extended diving. It is assumed that there would be neither requirements nor capabilities available for either

saturation diving or mixed gas diving. The limitation of using only air for diving yields a more simplistic diving arrangement and does not place any adverse restrictions on the pipeline installation methods.

The effects of oceanographic conditions on the pipeline, particularly in the surf zone, is another parameter which warrants consideration not only in the design of pipelines but in the method of construction. Currents and wave actions will affect the deployment of the pipeline from the shore and its in-place stability. In some instances these hydrographic effects may preclude the use of certain construction methods and equipment or pipe materials which may seem suitable initially. A detailed discussion of these environmental effects is presented in Appendix D. At this point, it is sufficient to call attention to their existence, since this should be thoroughly investigated during the study or design phase of a specific project, and it is not directly within the scope of this study.

3.4 UCT/NMCB MANPOWER AND EQUIPMENT

The UCT/NMCB have demonstrated that they have pipeline installation capabilities. They have installed nearshore pipelines using a variety of installation methods. These installations were relatively short, small diameter lines. Although military construction does not normally compete with commercial contractors, the same basic principles of good project management must be met. Time schedules and maximum utilization of available resources are critical elements. Basic resources available to the UCT/NMCB are its manpower and Tables of Allowance equipment.

Manpower and equipment available to the UCT/NMCB to construct nearshore pipelines will obviously vary from location to location and will depend on the extent of outside civilian and military personnel and equipment available. For purposes of this study it is assumed that only the personnel and equipment discussed in subsequent paragraphs are available for use.

3.4.1 Manpower

An examination of the list of personnel available for assignment to a UCT/NMCB pipeline installation project indicates that the basic skills required are available. These include welders, heavy equipment operators, divers, riggers, mechanics, etc. This does not mean that all personnel are highly skilled in construction methods or techniques, but assumes varying degrees of construction knowledge and skills for use during an installation. Even though the UCT/NMCB experiences a 100 percent (%) turnover in personnel every two to three years due to transfers, it may be reasonably assumed that the skill level of the units, as a whole, remains constant. An influx of new recruits enters at the apprentice level while apprentices advance and become journeymen. There are personnel within the organization who are military career oriented and, therefore, maintain a degree of expertise within the units, usually at a supervisory level.

Some speciality skills, such as pipeline welders, are not included in the list of personnel. During the discussion of various construction methods the speciality skills required by a specific method are noted.

Pipeline construction personnel are generally not "position" oriented but rather "task" oriented. For most tasks it makes little difference if a person holds a position as an apprentice or journeyman or master craftsman. Whether or not a person can satisfactorily perform a given task is of paramount importance bearing in mind that a less skilled person will take more time to accomplish the task or that more men may be required. It is concluded that the required skilled personnel are available but not necessarily in the required quantity. Therefore, additional time must be allowed for completing the project.

Two other considerations are recognized with regard to available personnel. One is the possibility of a virtually unlimited task force being available to the UCT/NMCB through other branches of the Navy as well as inter-military service cooperation with other branches of the armed forces. The other consists of obtaining any necessary expertise from private organizations on a consultant basis. Technical experts from the offshore pipeline construction industry functioning in a construction advisory capacity may be recruited on a project-by-project basis in order to optimize the construction effort .

Appendix E entitled UCT/NMCB Manpower contains a general listing of required construction personnel including job titles and job functions. No quantities are given as this would depend on the size, requirements, time constraints, and site conditions of a specific project. This listing was developed from an examination of past project work forces and actual jobs performed by Navy personnel. It is general in nature and was developed as an aid in determining the **types** of personnel available for the various construction methods. By comparing this list with the types of personnel required for a specific installation method, a generalized assessment was made of the manning limitations and capabilities of the UCT/NMCB. From this assessment personnel that may not be available were identified and listed as "Special Skills" in Tables 7-2, 7-3, and 7-4.

3.4.2 Equipment

The other element in assessing the UCT/NMCB capabilities and limitations for nearshore construction is determining the equipment available or adaptable to the construction methods under consideration. The primary basis for establishing an assessment of their capabilities was a review of the standard Tables of Allowance of equipment for an Underwater Construction Team and a Naval Mobile Construction Battalion. This was supplemented with additional information from Civil Engineering Laboratory personnel, observations, interviews, and literature

reviews. A generalized listing of applicable equipment extracted from the Tables of Allowance along with an abbreviated description and possible application is presented in Appendix F entitled UCT/NMCB Equipment. Comparing this list with the types of equipment required for a specific installation method resulted in the list of additional "Special Equipment" listed in Tables 7-2, 7-3, and 7-4 for each of the methods considered.

In addition to the Tables of Allowance, it is recognized that the UCT/NMCB may have open leasing agreements with several construction contractors to aid in securing additional necessary equipment. It is understood that this option exists and is taken into consideration in the assessment of their capabilities for a given construction method. However, no equipment from this source is specifically listed as being available for use by the UCT/NMCB.

One particular piece of equipment which merits attention for nearshore pipeline installations is the construction platform SEACON, an acronym for "sea construction". This platform is an altered YFNB hull which was redesigned for the installation and recovery of large objects, cable and pipe laying, underwater repair, diver support, and material transport. It is outfitted with a four-point mooring system, dynamic positioning equipment, a 50 ton gantry crane, and a protected 16 foot by 32 foot center-well. It has an open main deck space of 135 feet by 40 feet and may be fitted with additional lifting cranes and pulling winches which make it very suitable as a main or support platform for some nearshore construction methods. Figure 3-1 illustrates the profile and deck arrangement of SEACON.

It should be recognized that the equipment in the UCT/NMCB inventory is not specialized for the sole purpose of pipeline construction. However, like most construction equipment, it may be adaptable to certain aspects of offshore construction and, with some slight modifications and ingenuity, may prove to be quite successful.

In summary, it is difficult to make a comprehensive assessment of the UCT/NMCB available equipment or manpower as applied to nearshore pipeline installations, but establishing a preliminary assessment of their capabilities and limitations is necessary as a basis for determining construction methods which are most applicable to their present and future needs. It is felt that a conservative approach is preferable due to the broad scope of this study. The requirements of a specific project will determine the specific manpower and equipment necessary to successfully execute a given method.

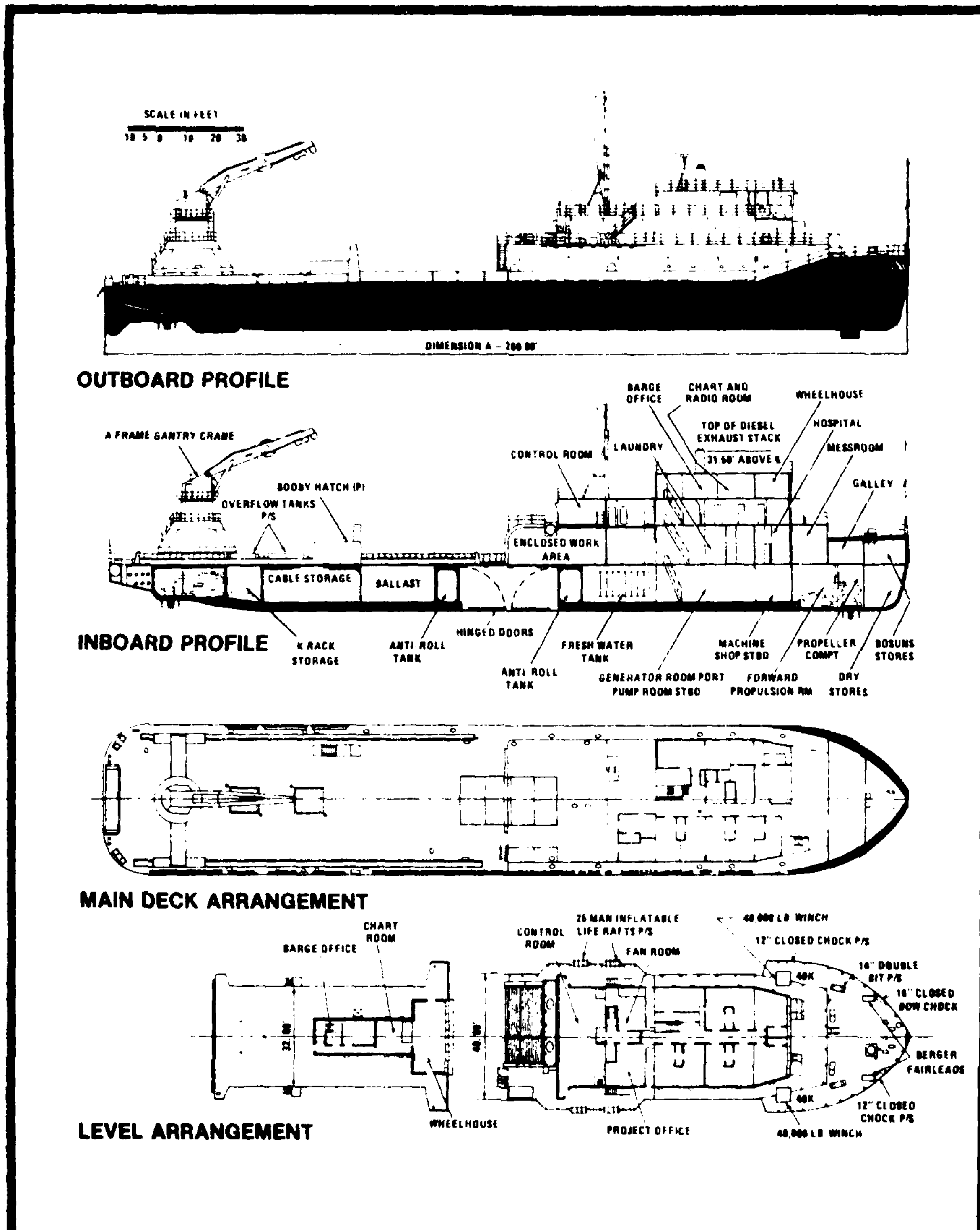

FIGURE 3-1 SEACON PROFILE AND DECK ARRANGEMENT *	
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DATE: FEB. 9, 1981	SCALE: AS SHOWN
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* FROM: "SEACON" BROCHURE, CHESAPEAKE DIVISION, NAVAL FACILITIES ENGINEERING COMMAND, WASHINGTON NAVY YARD, WASHINGTON, D.C. 20374

CHAPTER 4

EVALUATION OF INSTALLATION ELEMENTS

4.0 GENERAL

Four of the most important elements which affect the selection and evaluation of a marine pipeline construction method are pipe material, method of stabilization, site conditions, and pipe coupling/connection. Little can be done to alter site conditions beyond minimization of their effects by proper route selection. Site conditions assumed for this study are discussed in Chapter 3 and Appendix C.

Pipe material, stabilization, and coupling/connection are elements which must be selected for each project and are, therefore, controllable. Pipe material refers to the base material from which the pipe is made (for example, steel, plastic, cast iron, reinforced concrete, etc.) Stabilization refers to the method used to restrain the pipeline to insure than it will remain in place after installation. Current and wave induced forces are the primary forces which must be resisted. Pipe coupling/connection refers to the method used to join the lengths of pipe (called "joints") together to form longer pipe sections (called "strings"). Methods of joining pipe are discussed in Section 4.3.

Pipe external coatings and internal linings are discussed in Section 4.6.

4.1 FACTORS TO CONSIDER IN SELECTION OF PIPE MATERIAL

Pipe materials are usually selected during the design phase of a project. Factors considered during the evaluation include cost (both material and installation), operating requirements (internal pressure, fluid temperature, external forces, etc.), material availability, and construction method constraints.

Structurally the pipe material must be able to:

a) Support its own weight, including line content, over the expected unsupported pipe spans due to bottom irregularities.
b) Withstand environmental forces and forces due to backfill materials.
c) Withstand the required internal and external pressure without exceeding the pipe material's yield strength.
d) Withstand reasonable combinations of the above forces.

Many of the pipe coupling/connection techniques are weaker than the primary pipe material. This must be considered in the structural analysis.

For most offshore pipelines, the greatest structural loads occur during installation. Therefore, it is imperative that a structural analysis of the pipeline or pipe sections be made after both selecting an installation method and reviewing the proposed construction procedures.

4.2 PIPE MATERIALS

Nearshore pipelines were originally either cast iron or concrete pipe, with occasional use of wrought iron. More recent pipelines have used steel or plastic to reduce material costs and/or to increase the construction production rate, which also reduces costs. Steel pipe has been the preferred material of the offshore gas and oil industry for about a quarter of a century.

Materials considered state-of-the-art are listed below and discussed in some detail in subsequent paragraphs.

a) Coated steel.
b) Flexible.
c) Plastic.
d) Aluminum.
e) Asbestos bonded corrugated metal.
f) Asbestos-cement.
g) Cast iron.
h) Reinforced concrete.
i) Wrought iron.

4.2.1 Coated Steel

Steel pipe has been installed extensively for many years in the oil and gas industry for subaqueous work because it allows a great degree of flexibility in construction techniques and it has good physical properties. Steel is stronger than cast iron, and since the specific gravities of these two materials are virtually the same, pipes for the same application in steel are lighter due to the use of a lessor wass thickness. Generally speaking, steel pipes are cheaper, easier to transport, and easier to construct than cast iron or wrought iron pipe. Steel pipe is available in standard diameters up to 60 inch. Stand-ard lengths of steel pipe sizes vary, but they usually range from 20 to 40 feet.

Steel pipes for marine use are usually joined by welding, although flanged or other mechanical connections are sometimes used. When the pipes are joined by welding, the welds are usually checked by radiographic inspection (X-ray technique) to assure weld quality.

A major disadvantage of steel in sea water environments is its limited resistance to corrosion. However, experience in the oil, gas, and water supply industries has proven that a properly coated steel pipeline with cathodic protection will last almost indefinitely.

Because of the requirement to protect steel against corrosion, the initial cost of steel pipe may be more expensive than some flexible pipe or plastic pipe. Construction costs, however, may be lower than most metallic pipe as steel pipe is readily adaptable to more construction methods allowing greater construction flexibility. Steel pipe's real economy lies in its adaptability to rapid fabrication and installation, joint sealing quality, inherent structural integrity, and high pressure capacity. However, a thorough comparison between other pipe materials would be wise to assure that steel is the most suitable material for a specific application and construction method.

4.2.2 Flexible

For the purpose of this report flexible pipe denotes pipe which is designed to bend or flex in relatively short radii without damage or adverse effects to the physical or operating characteristics of the pipe. Examples are Simplex "Reel-Pipe", and "Coflexip" pipe, or hose. Flexible pipes have the distinct capability of being able to accept large structural displacements without inducing intolerable stresses. However, there are limits to its flexibility.

As the classification implies, the prime advantage of flexible pipe is that it flexes without yielding or damaging the pipe material. This allows new applications of pipe design and laying techniques. The laying stresses and tensioning requirements present during deep water construction are far less critical for flexible pipe than for steel and other pipe materials. Pipe laying and underwater connections are easier with flexible pipe since it has comparatively low stiffness coefficients in both torsion and bending. This allows divers to easily align the pipe for underwater connections.

While the repair of damaged steel or other types of pipe material may or may not be difficult due to the nature and extent of the damage, flexible pipe may be easily lifted to the surface for repairs without incurring the bending stresses or possible pipe buckling associated with other stiffer pipes. It is implicit that flexible pipe may be installed in heavier sea conditions than rigid or semi-rigid pipe.

Flexible pipes are easier to recover than rigid or semi-rigid pipes. Flexible pipe may be re-reeled on the same equipment using the same basic technique as had been used to install it.

Manufacturing technology can produce flexible pipe in continuous lengths which are virtually unlimited. For example, continuous lengths of about one mile of 6 inch pipe have been installed with only light marine support. The length limiting factors are the transportation and handling constraints.

Use of the reel method for laying this type of pipe yields two inherent advantages. One is speed of the pipe laying operation, which is essentially a function of the lay-vessel's positioning capability and speed. The other is the simplicity and compactness of the reel system itself. This is a self-contained system including the necessary holdback tensioning devices if they are required.

Three types of flexible pipe will be specifically addressed in this section. They are:

a) "Coflexip" as manufactured by Coflexip and Services, Inc., Paris, France.
b) "Reel-Pipe" as manufactured by Simplex Wire and Cable Co., New Hampshire, U.S.A.
c) Hose.

Coflexip is the most advanced flexible pipe presently available. It is suitable for extremely high pressures - up to 23,000 psig internal and 3,000 psig external hydrostatic pressures. It is currently available in sizes up to 22 inches with a minimum bending radius of ten to fifteen times the pipe diameter.

Coflexip pipe is basically composed of steel and thermoplastic materials. A typical pipe structure consists of the following components (See Figure 4-1):

a) Internal thermoplastic sheath - makes the pipe leakproof and resists corrosion and abrasion.
b) Interlocked Z-shaped steel or stainless steel carcass - resists internal and external pressures and retains flexibility and short bending radius.
c) Intermediate thermoplastic sheath - keeps the internal sheath from collapsing should the external sheath be damaged (optional).
d) Double crosswound tensile armors of steel or stainless steel wound on a biased axis, or helix - resists axial loads and torsional strain.
e) External thermoplastic sheath - protects the metallic structural layers against abrasion and corrosion and binds the tensile armors.
f) End couplings - provides mating capability with standard pipe couplings such as flanges and hubs.

The main disadvantage of Coflexip pipe is cost. It is the most expensive pipe material encountered due to its advanced design and high pressure capabilities. However, for a specific application it may be the most suitable pipe material.

Reel-Pipe is a polyethylene liner pipe with an armored outer covering for strength and protection which has been designed

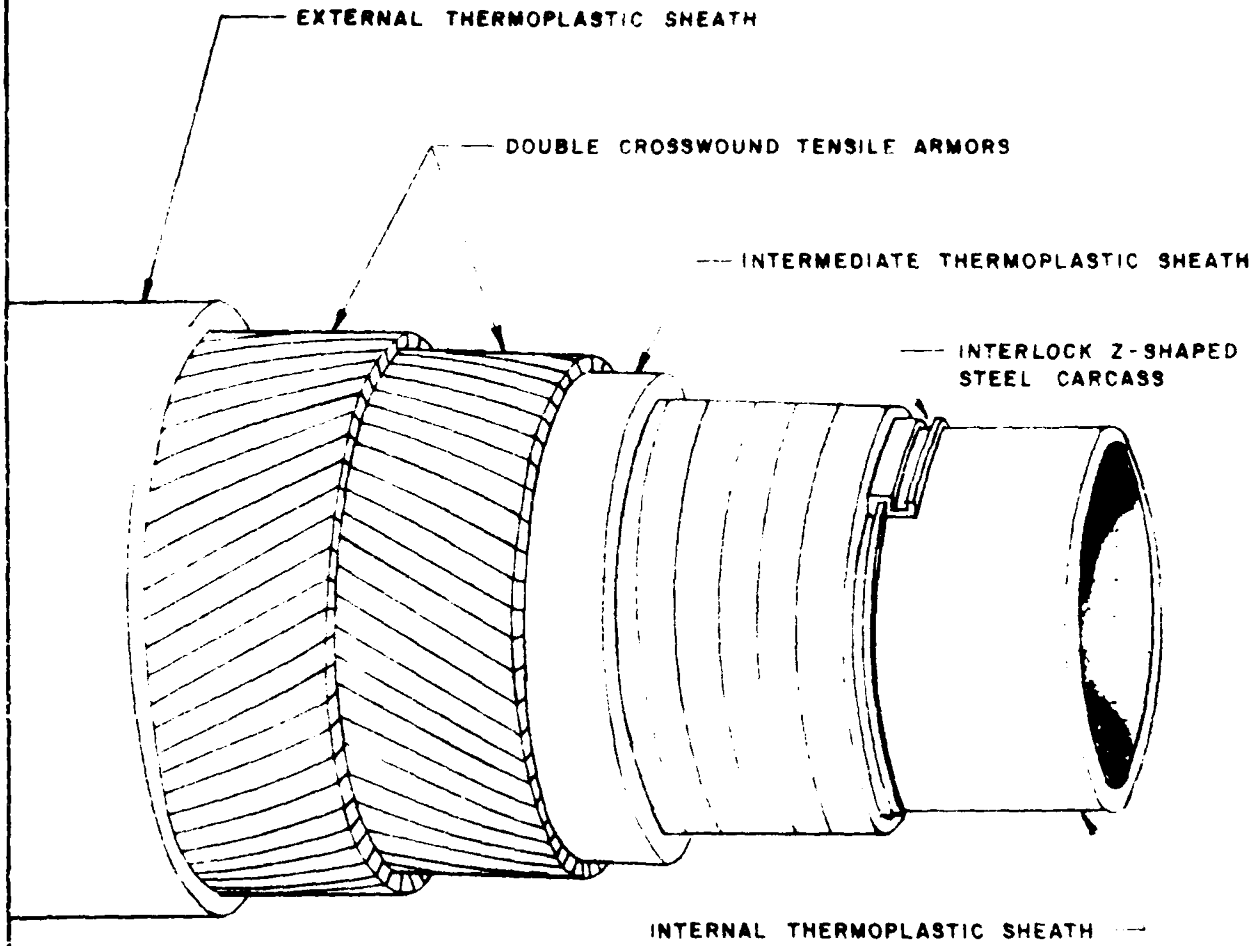

FIGURE 4-1
TYPICAL "COFLEXIP"
PIPE STRUCTURE

DRAWN BY J DENTON	APPROVED: B.W.M.
DATE 1-23-81	SCALE NONE
DMJM	8413-01-01

for the reel method of pipe laying. It is currently available in diameters of 6 inches and less. Sizes from 12 to 16 inches and design pressures to 3,000 psig are possible with existing technology.

Reel-Pipe consists of the following basic components (See Figure 4-2):

a) Internal flexible liner of extruded medium or high density polyethylene - makes the pipe leakproof and resists corrosion and abrasion.
b) Bedding of synthetic fiber rovings tightly wound around the liner - provides a bedding for the armor wires.
c) Armor wires of round, galvanized steel - provides a full, uniform cover of protection and axial strength. The wires are applied helically and completely around. They may be coated with a preservative compound or extruded plastic for corrosion protection.
d) Outer binder of helically applied synthetic fiber (normally flooded with a tar compound) - functions as a preservative and binder.
e) Outer covering - provides protection and acts as an outer surface for handling (optional).
f) End couplings - provides mating capability with standard pipe couplings such as flanges and hubs.

Reel-Pipe is relatively inexpensive as compared to Coflexip pipe. Its limitations are the same as polyethylene material (see Section 4.2.3) with regards to the internal liner. A disadvantage is the non-availability of sizes larger than 6 inches.

It should be noted that Simplex has reel systems available for the Simplex Reel-Pipe. The reel system includes the reel stand, yokes, and reel which may be mounted on a barge. The largest units available have a 126 inch reel head and are capable of spooling about 3000 feet of 4 inch reel pipe. For long pipe lines several reels may be used or longer lengths of Reel Pipe may be coiled in a barge crib. Figure 4-3 shows a barge mounted reel system.

Hose may be a viable alternate for flexible pipes for a particular project. However, hose does not meet the criteria established for this study. In particular, the design and implementation of a pipeline system using hose which would meet the established criteria, especially the design life of at least 15 years, is not considered resource efficient. Better alternative materials are available for permanent installations.

Neglecting the problems of on-bottom pipeline stability and design life, the type of hose construction which would meet the

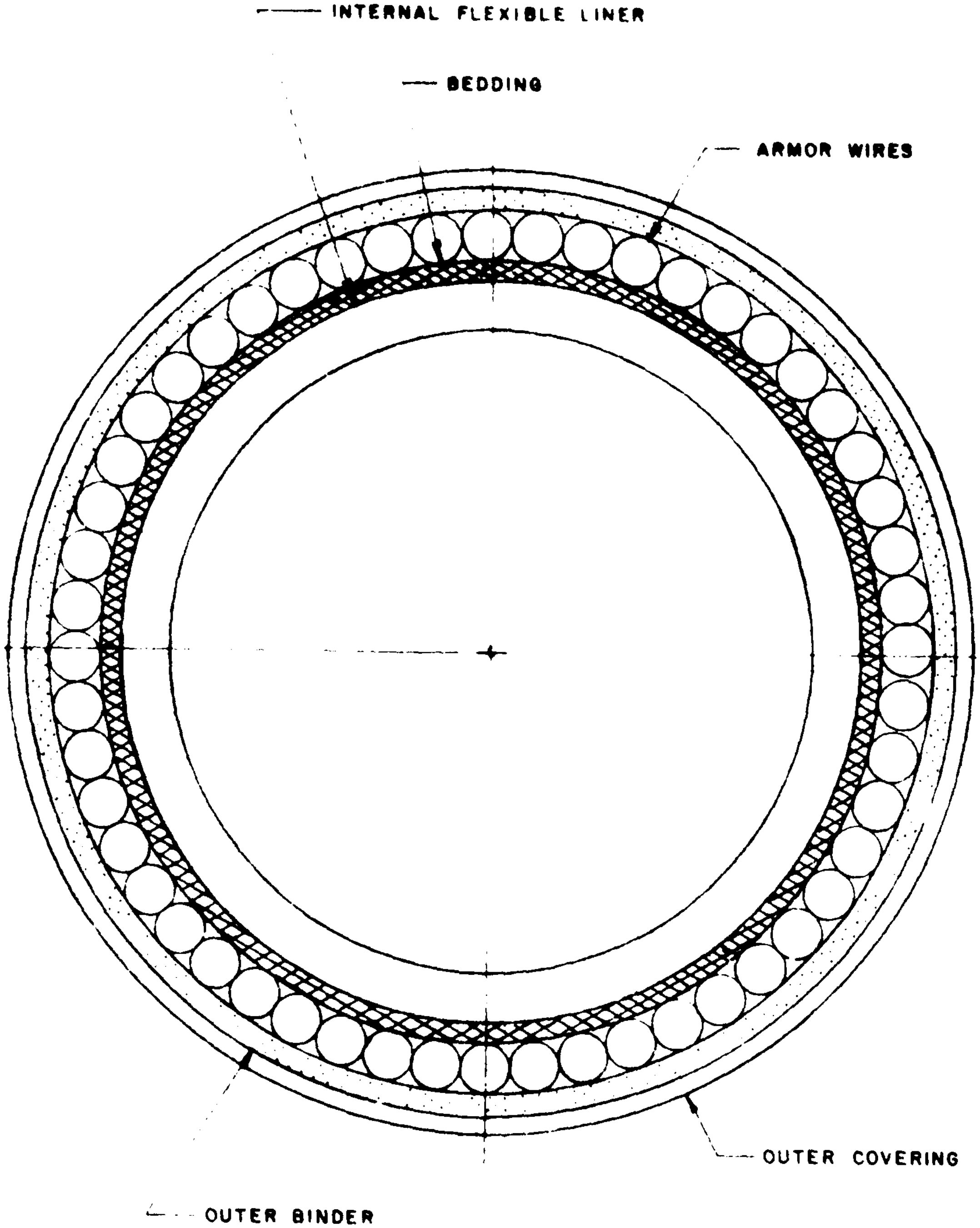

FIGURE 4-2
TYPICAL "REEL-PIPE"
PIPE STRUCTURE

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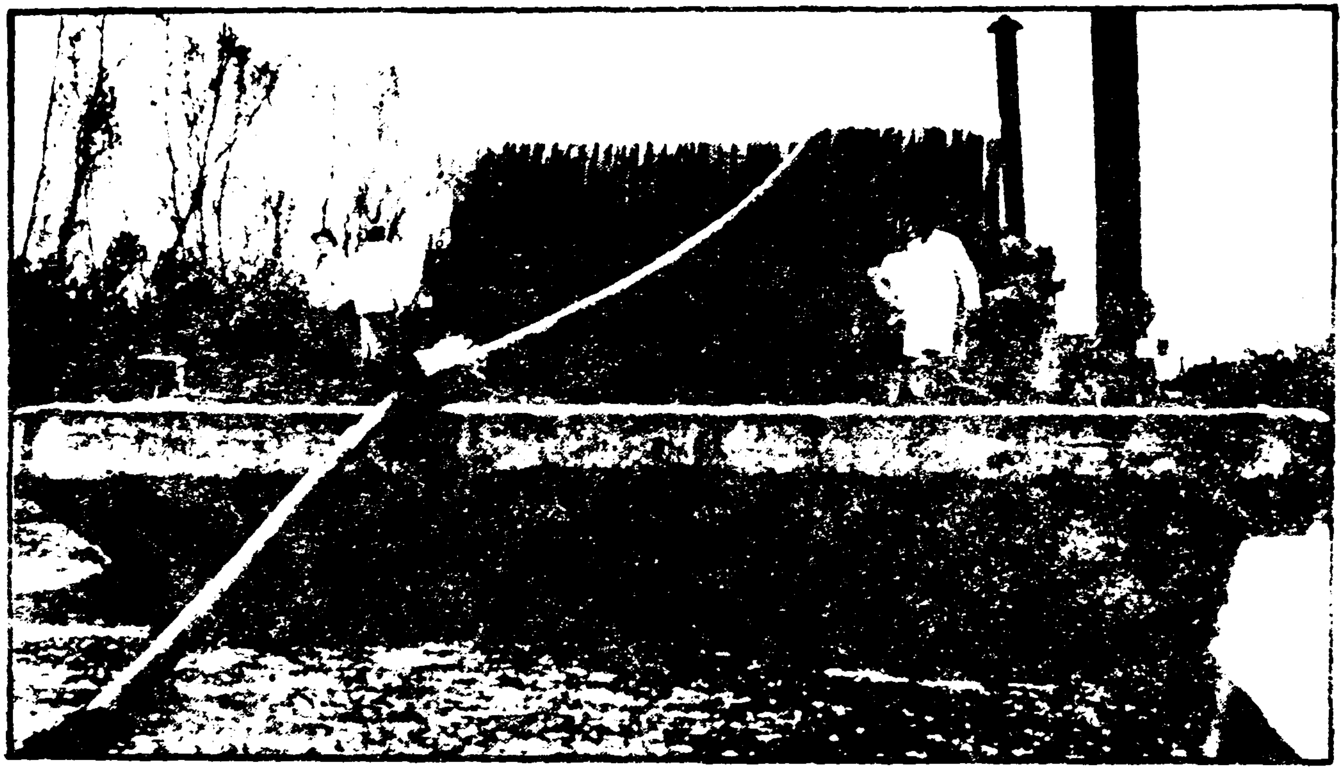

FIGURE 4-3
SIMPLEX REEL MOUNTED
ON BARGE

DRAWN BY: M RICH	APPROVED: B.W.M
DATE: APRIL 28, 1981	SCALE: NONE
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other criteria would be a multi-purpose chemical hose with an inner tube resistant to hydrocarbons and most general chemicals. It would be reinforced with two textile braids and one flexible steel wire helix to resist circumferential and axial forces. The outer cover of the hose should be resistant to abrasion and to marine life and be designed for subsea application.

Hose is available in only limited sizes. Generally, hose which can meet the operating parameters are readily available in sizes 12 inches in diameter and less.

4.2.3 Plastic

Recent developments in the technology of plastics have made possible the manufacture of some plastic, non-metallic pipe in diameters up to 144 inches. However, for marine pipelines the practical upper diameter limits are less because acceptable joint connection techniques are not currently available. Twenty-four inch pipe is readily available in almost all plastic pipe materials.

Common types of plastic pipe available are listed below.

Plastic Material	Maximum Diameter for Acceptable Joints, inches	Standard Lengths, feet
Fiberglass Reinforced Epoxy (FRP)	36	various
High Density Polyethylene (HDPE)	48	40
Polybutylene (PB)	24	various
Polyvinyl Chloride (PVC)	24	20

Excellent corrosion resistance is a significant advantage of plastic pipe. Thermoplastic pipe should not be used for hot effluents since heat weakens its mechanical properties. However, it is within the temperature criteria established for this study and presents no significant problems. From an initial material cost standpoint plastic pipe is competitive with coated steel, more expensive than reinforced concrete pipe (RCP), and less expensive that cast or wrought iron pipe. Thermoplastic pipe has a specific gravity of about 0.92 to 0.96; therefore, it floats even when filled with water.

Its lightness facilitates handling and may reduce installation costs in areas where its lower strength and lighter weight are not disadvantages. A high ocean current location is an example where lighter weight may be a detriment.

Plastic pipe is almost always installed by a pull method. It is joined, weights added as it is pulled into place, and sunk by controlled flow of water into the empty pipe. To provide on-bottom stability a number of weights or anchors may be added as required. Its use should be limited to protected waters or thoroughly investigated by a highly qualified engineering effort on a project-by-project basis.

There are two major groupings of pipe in this category:

Reinforced Thermosetting Resin Pipe - commonly called fiberglass reinforced pipe (FRP). The resin used for this type of plastic is a thermoset type which maintains strength through its range of temperature. It is not re-shaped by temperature. The resin is reinforced with glass fiber either by filament winding, contact hand-lay-up molding, or casting.

Pipe is available up to 144 inch diameter with pressure capability up to 150 psig. Temperature limitation is 200° F.

FRP has many positive features, but long term experience as a marine pipe material is not available. A point of concern with FRP, for example, is delamination of the resin and fiber layers. In addition, experience with FRP marine pipelines has shown that these pipes can suffer rapid wear from abrasion on the sea bottom if they are not properly bedded and stabilized. Rock backfill has also been known to puncture FRP.

Thermoplastics - made from plastic resins that can be reshaped by heating. Thermoplastic pipe is made primarily by extrusion. There are several different types of plastics, and the pressure-temperature capabilities vary with each type. In general, the maximum working temperature is less than FRP. Pressure capabilities up to 150 psig are available.

a. Polyethylene is available in three density grades: high (HDPE), medium (MDPE), and low (LDPE) density. In recent years, only medium and high density polyethylene materials have been used for pipe. As density increases, tensile strength, surface hardness, stiffness, soften temperature, and chemical resistance increase.

   Ultra-high molecular weight HDPE pipe is practically chemically inert. Natural chemicals in soils will not degrade the material. It does not conduct electrical current, therefore, it will not corrode by electrolytic action. It does not rot, nor is it affected by algae, bacteria, or fungi, and it is resistant to marine biological attack. Liquid hydrocarbons will permeate the pipe wall and reduce the hydrostatic strength, but they will not degrade the material itself. At elevated temperatures (140°F) HDPE is not satisfactory for transporting some liquid petroleum

products including gasoline, fuel oils, or oils. A thorough investigation for specific applications at elevated temperatures must be made to assure a proper design with HDPE pipe.

Another advantage of HDPE is its overall toughness. It flexes and absorbs impact loads and it may be cold bent in the field to a minimum radius of about ten to fifteen times its diameter. It may be deformed without damage or adverse effects to the service life. This characteristic makes it suitable for spooling on reels for rapid pipe laying by the reel method, particularly for small diameters.

The joints of HDPE pipe (about 40 feet in length) are rapidly joined together by the butt fusion technique. With this joining method, the ends of two pipe joints are squarely machined by a special planing tool, softened by heating, and pressed together to form the butt fusion joint. Curing of the joint consists only of cooling which is completed in a matter of minutes. Mechanical joints, such as steel or alloy flanges, can be fitted onto special molded pieces of HDPE pipe. The butt fusion technique of joining will be discussed in detail in the section on pipe coupling/connection.

Another primary advantage is its light weight. With a specific gravity of about 0.95, it floats in water. Since it is 70% to 90% lighter than concrete, cast iron, or steel it is much easier to handle. Substantial cost savings may be realized by reduced manpower and equipment requirements.

High density polyethylene pipe is recommended as a viable pipe material. It is highly adaptable to installation methods within the UCT/NMCB capabilities. However, a special machine for joining the pipe is required for making the butt fusion joints, and an investigation is required to assure proper application for a particular project.

b. Polybutylene is very similar to HDPE pipe within a temperature range of 180°F. It utilizes the same butt-type joints as HDPE but joints require 24 hours to 7 days curing time because it is a chemical bonding and not a fusion or heat bond.

   This pipe material is not recommended for UCT/NMCB application because of the extended joint connection curing time. It has no real advantages over other plastic pipe materials.

c. Polyvinyl chloride pipe is primarily a small diameter pipe material, although it is available in 24 inch diameter

for pressures to 150 psig and temperatures under 150°F. Due to its low structural strength and its susceptibility to attack by marine life, PVC is seldom used for marine pipelines. Therefore, it is not recommended as a pipe material for marine application. Other pipe materials are better suited.

4.2.4 Aluminum

Aluminum has been used as a pipe material in onshore and in some offshore applications for a significant length of time. It may be joined by conventional mechanical joints, welding, or in some cases by adhesive bonding. Pipe sections in most cases are joined by the welding process. The joining technique used is usually governed by the type of service, the number of joints required, the availability of skilled craftsmen and equipment, and the pipe diameter and wall thickness.

One prime advantage of aluminum pipe is its light weight which facilitiates handling, transportation, and reduces equipment requirements. However, its light weight requires the pipe be stabilized for marine application.

Cathodic protection of aluminum pipe presents a special problem in that aluminum is susceptible to alkaline attack. If excessive cathodic protection is applied, the reaction at the cathode, which generates alkalinity at the surface of the aluminum, may actually corrode the aluminum pipe faster than if it were not protected at all.

Aluminum pipe is more expensive than steel and plastic. The added costs of corrosion protection and stabilization precludes it from being recommended as a pipe material. However, it is recognized that it is a viable pipe material and may be well suited for a specific application. It is felt that other pipe materials are better suited for nearshore pipelines.

4.2.5 Asbestos Bonded Corrugated Metal

Asbestos bonded corrugated metal pipe has been used for many onshore sewage pipeline installations over the past 35 years, and it has an excellent service life. A relatively recent development in the manufacturing process makes possible a smooth interior, thereby providing the same or lower friction characteristics as other smooth-walled pipes. It is not suitable for pressure service due to the nature of its joint connections. However, it may be economical for relatively low pressure gravity lines. The pipe itself is not costly, but it requires a rather firm bed and good grade because of the joints. It may be suitable for short length joint-by-joint construction methods with joint connection on the seabed; however, the requirements for more delicate handling and more restrictive bedding limit its practicality.

This pipe material is not recommended for UCT/NMCB application. It may be of limited value in outfall pipeline applications but it does not meet the pressure and service criteria established for this study. Additionally, the restrictions imposed by bedding requirements and limited construction methods render it unsuitable.

4.2.6 Asbestos-Cement

This pipe is formed from pressed and bonded asbestos fibers and cement. It is a rigid pipe which requires a joint-by-joint method of in-place assembly. This limits the methods of construction to on-bottom, seabed pipe connections, which is not considered as resource efficient as other methods and materials.

Asbestos-cement pipe was primarily designed as a water and wastewater pipe material. As such, the ring gasket for effecting joint seals would have to be specially made of a compound which is resistant to hydrocarbons. This would require some development as these gaskets are not readily available for hydrocarbon service.

This pipe is not recommended for use by the UCT/NMCB for nearshore installations except on a specific project basis.

4.2.7 Cast Iron

Historically, cast iron has been one of the most popular of all pipe materials for nearshore outfall pipelines and some water lines. It has not been used very much for pressure applications in marine environments. Its strength approaches that of steel pipe and it has corrosion resistant properties in sea water which are superior to unprotected steel pipe. It has fair to poor flexibility and impact resistance, and it is more expensive than other types of pipe. It is very seldom used offshore today. Cast iron is commercially available in various diameters through 54 inches. The standard lengths vary depending upon the process used to make the pipe and the pipe end connection specified (such as flanged); however, 20 foot lengths are most common. Connection design is of critical importance to the stability, efficiency, and useful life of the pipe. The connections must provide a tight seal, should prevent pullout, and should be flexible in many instances. Flanged and bell-and-spigot connections are the most common.

The relatively weak connection designs and short manufactured lengths limit the installation of cast iron pipe to the joint-by-joint method where each joint is connected on the seabed. This limitation on construction method flexibility makes cast iron more expensive as a pipe material by increasing the installation costs.

Cast iron pipe as a material for offshore pipeline construction is not recommended, except for a specific project application. Its disadvantages are brittleness, types of joint connections available, and limited adaptability to methods of construction which are resource efficient. Other pipe materials are better suited to UCT/NMCB requirements.

4.2.8 Reinforced Concrete

Concrete pipe is primarily used for large diameter marine outfall pipelines. Concrete pipe has not been used extensively in small diameters (24 inches and less). The special care required to make underwater joints and the bedding requirements generally have led to the use of other pipe materials. Even though concrete pipe is initially less expensive than cast iron, wrought iron, or coated steel, installation costs can be quite high. Concrete pipe has excellent resistance to attack by sea water or marine organisms, but it is not well suited for transporting liquid petroleum products because of its low pressure joints and the general limitations of concrete to carry tensile loads.

For concrete outfall pipelines, where the number of sections required is very large, virtually any desired section length under 32 feet can be specified. RCP operating under relatively high pressures for outfall lines is manufactured with a watertight flexible-expansion joint. The joints are bell-and-spigot type with the joint surfaces being formed by steel rings in the ends of the pipe. For pipe operating under low pressures or gravity flow, a rubber gasket is used to make the joint watertight. A rectangular groove is provided on the spigot end and into it a continuous round rubber gasket is placed. As the pipes are pushed together, this gasket is compressed into the groove by the flared portion of the bell. When the pipe is pushed into position, the gasket is confined on all four sides, which provides a good joint seal.

Reinforced concrete pipe is not recommended for UCT/NMCB application. It does not meet the criteria for pressure nor the capability to transport liquid hydrocarbons, namely petroleum products. Construction methods are limited to techniques which allow joint connections on the seabed. Also, it must have a properly bedded foundation. Except for large dia-meter outfall pipelines, it has limited practical use in marine pipeline applications.

4.2.9 Wrought Iron

Wrought iron pipe has been used for several West Coast wastewater outfall pipelines and several water line crossings of bays and streams. Joints may be welded or mechanical-type couplings can be used. It lends itself to construction by joint-by-joint methods of seabed joining. Manufacturers claim

that its corrosion resistant properties are superior to cast iron, particularly in salt water environments. The maximum diameter currently available is 42 inches.

Like cast iron, wrought iron is not recommended for UCT/NMCB's application, except for a specific project requirement. It does not lend itself to construction methods which are resource efficient.

4.3 PIPE COUPLINGS/CONNECTIONS

Pipe couplings or connection methods are not specifically designated in the study objectives. However, the joining method often dictates or limits either the pipe material or the construction method. A summary of the type of joints or methods of joining pipes is presented in this section. Table 4-1 depicts the pipe materials of construction and which types of connections are available. Joint types include:

a) Butt Weld
b) Screw
c) Bell-and-Spigot:
   1. gasket joint
   2. glue joint
d) Flange
e) Collar/Gasket
f) Cold or Hot-Pour
g) Specialty Couplings:
   1. adhesive bonding
   2. butt fusion (HDPE)
   3. swaged coupling
   4. buckle joint
   5. quick coupling
   6. "Cryofit"
   7. "Betalloy"

4.3.1 Butt Weld

Butt welding is the method most commonly used for joining metallic pipe. Except for cast iron, most metal pipe is ideally suited for joining by welding.

Welding is basically a fusion process where the pipe (or "parent") metal is heated to a liquified state and a filler metal is added to produce a welded joint. The structural strength of a properly welded joint is at least equal to the strength of the pipe. Welding has several advantages including:

a) Positive, leak-proof joints with high structural integrity.
b) Ideally suited for testing via radiographic methods to assure weld integrity.
c) Well suited for production line techniques.
d) Low cost per completed joint.

TABLE 4-1

COUPLINGS/ CONNECTIONS	Coated Steel	Flexible Coflexip	Flexible Simplex	Flexible Hose	Plastic FRP	Plastic HDPE	Aluminum	Asbestos Bonded	Corrugated Metal	Asbestos Cement	Cast Iron	Reinforced Concrete	Wrought Iron
Butt Weld	X						X						X
Screw	X	X	X	X	X		X						X
Bell & Spigot:													
Gasket joint					X			X*		X	X*	X*	X*
Glue joint					X								
Flange	X	X	X	X	X	X	X	X			X		X
Collar/Gasket	X				X	X	X						
Cold or Hot-Pour											X	X*	X
Specialty Couplings:													
Adhesive bonding					X								
Butt fusion (HDPE)						X							
Swaged coupling	X						X						
Buckle joint	X						X						
Quick coupling	X	X	X	X			X						
Lead joint											X		X
"Cryofit"	X												
"Betalloy"	X												

* NOT FOR PRESSURE APPLICATION

This joining method requires welding machines and skilled personnel trained for pipeline welding. Figure 4-4 illustrates a typical pipeline butt weld. Underwater welding may be accomplished with special equipment. "Wet welding" causes weld metal cracking and embrittlement due to the high oxygen and hydrogen content present in the water and due to the high quench rate of the welded pipe. Hyperbaric and one atmosphere underwater dry welding utilizes a sophisticated complement of equipment. A typical hyperbaric or one atmosphere underwater welding and alignment fixture is illustrated in Figure 4-5.

Two basic methods of pipeline welding are used. These are oxy-acetylene or torch welding and electric shielded arc welding. Generally, oxy-acetylene welding is no longer used for production welding except in special instances.

Basic steps for welding joints together are:

a) Beveling and cleaning the two pipe ends to be joined.
b) Aligning the two pipe ends via internal or external line-up clamps.
c) Welding the joint either by a manual or automatic welding process.
d) Inspecting the completed joint.

The three principle methods of shielded arc welding are:

a) Conventional arc welding.
b) Gas metal-arc welding (MIG).
c) Gas tungsten-arc welding (TIG).

Steel may be conventional arc welded while aluminum requires gas tunsten-arc welding.

4.3.2 Screw

Screwed couplings with a buttress-type thread are generally available for the full range of pipe sizes. Sizes for 12 inch diameter and less are readily available while larger sizes may be special ordered. No special skills are required for joint make-up. A suitable anti-seize joint compound should be applied to the coupling threads prior to joint make-up to prevent thread damage and subsequent joint leaks.

Screwed couplings include pipe which is either threaded male on one end and threaded female on the other or threaded male connections on both ends with a threaded collar as a coupling.

Female threaded ends are usually upset or expanded. The collar-type coupling is the most common. These types are illustrated in Figure 4-6.

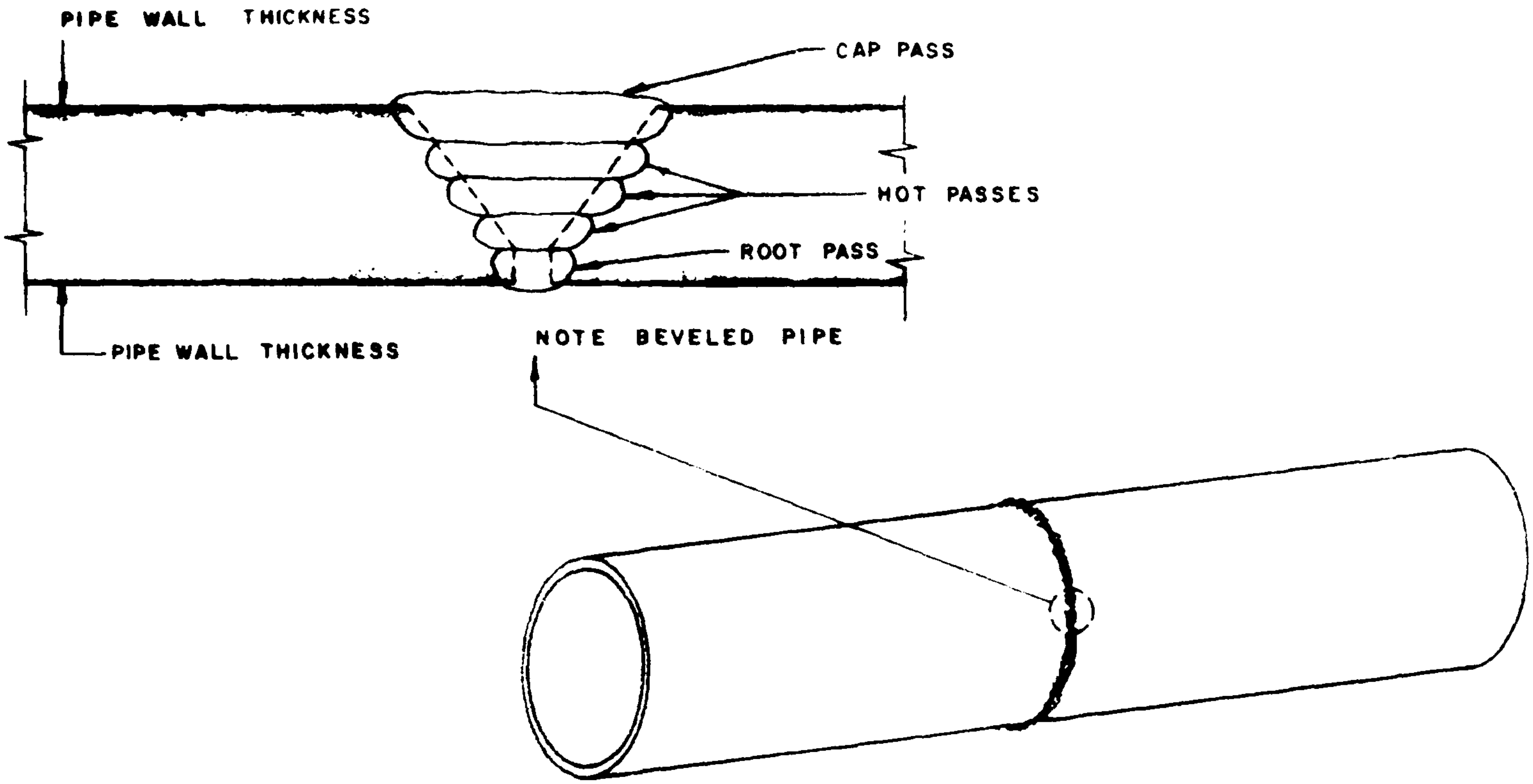

FIGURE 4-4 STEEL PIPE SHOWING WELDED JOINT	
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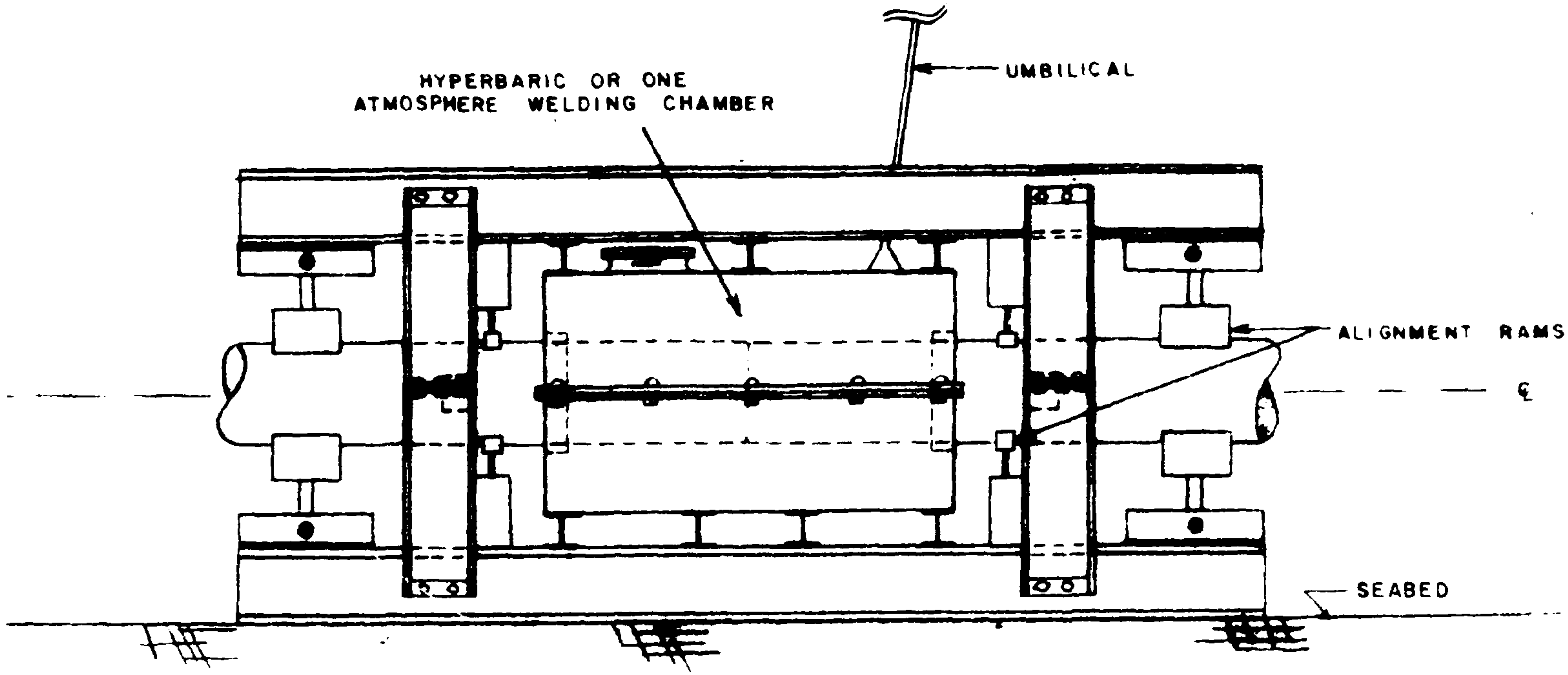

FIGURE 4-5
UNDERWATER WELDING AND
ALIGNMENT FRAME

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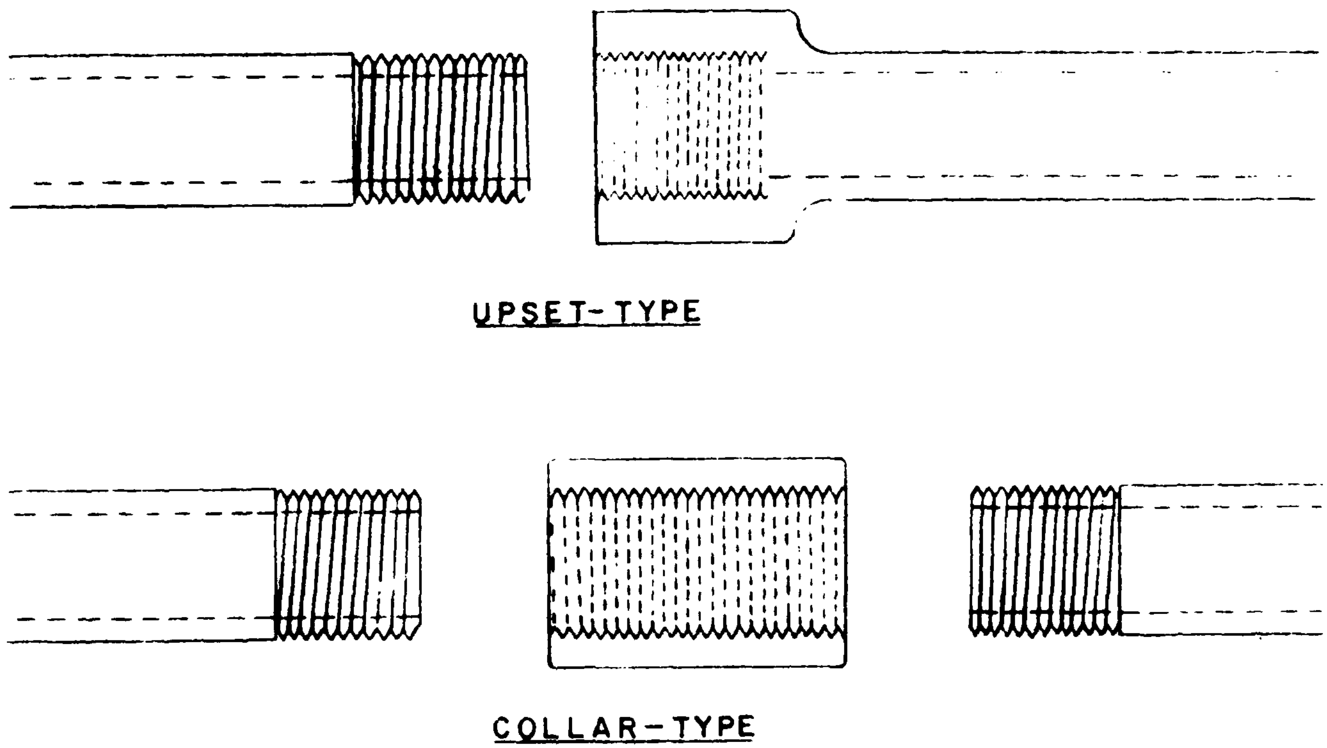

FIGURE 4-6 SCREWED COUPLINGS	
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4.3.3 Bell-and-spigot

Bell-and-spigot connections may be a gasket-type or glue-type. The double-spigot/collar is considered in the bell-and-spigot classification because the collar is usually on one end of the pipe before joint make-up and is then connected together as a bell-and-spigot assembly.

Generally, the gasket-type joint is for gravity flow pipelines or lines with little pressure (less then 10 psig). An exception is the gasket joint for asbestos-cement pipe which is specially designed for pressure applications primarily in the water and wastewater industry.

The gasket is usually a synthetic rubber ring which is fitted into a groove made on the spigot-end of the pipe. The bell-end is a tapered flare which deforms the gasket into the groove to form a seal when the joint is completed. Joints of this type are found on reinforced concrete pipe. Another type of gasket-joint is made when a gasket is placed in a groove in a bell-end (for example asbestos-cement) or a gasket is made as an integral part of the pipe's bell (such as polyvinyl chloride).

Bell-and-spigot joints may be glued together, also. This is generally reserved for plastic pipe which may be glued with an epoxy glue or other chemical bonding, such as fiberglass reinforced plastic pipe.

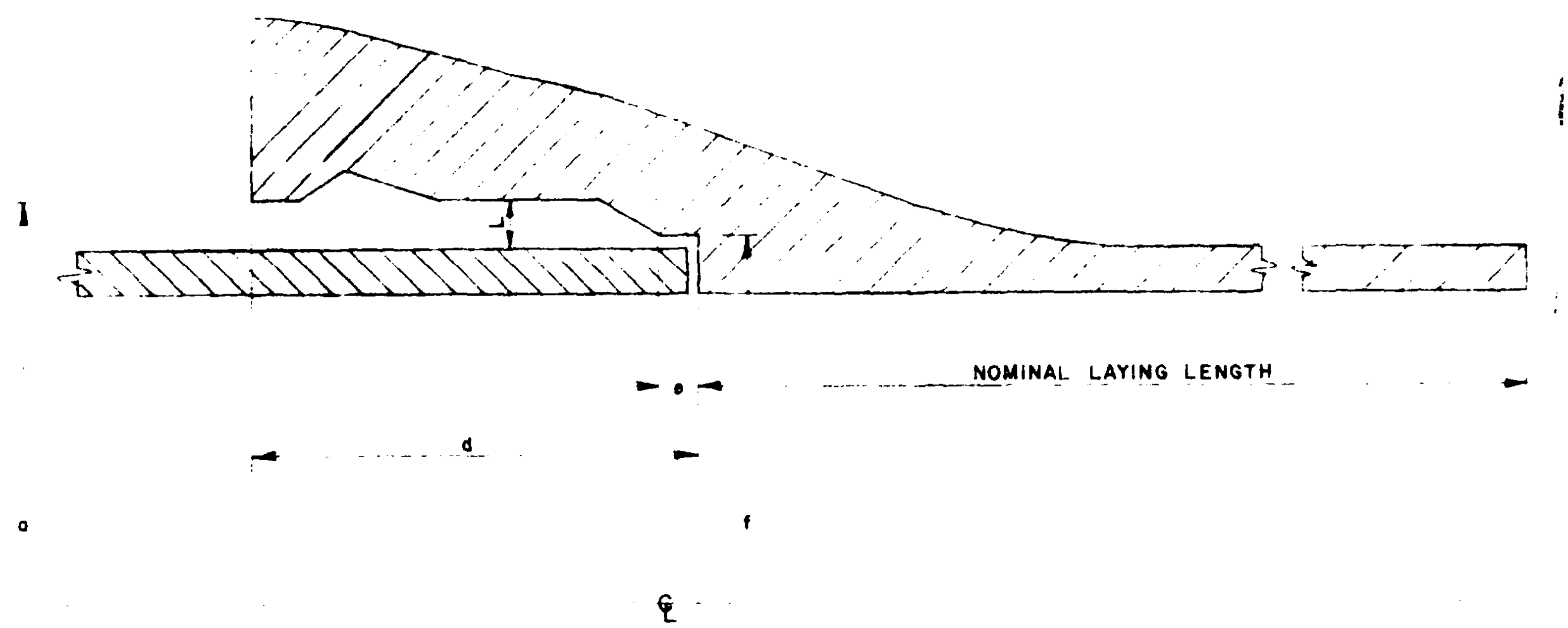
Bell-and-spigot type joints are usually available throughout the size range of pipe materials which employ bell-and-spigot connections.

This method of joint connection is very fast and requires no special skills or equipment. However, it is generally limited to very low or no pressure applications and requires a method of construction using a joint-by-joint laying technique. A bell-and-spigot joint is shown as Figure 4-7.

4.3.4 Flange

Flanged joints are popular for metal pipes and for joining pipes of different materials, such as steel to high density polyethylene. Flanges may be joined to the pipe by different methods. Steel pipe may be welded or screwed, FRP may be screwed or used with a special transition piece. The flange may require a special transition piece, such as with FRP and HDPE pipe, but flange-to-flange make-up is a common pipeline joining method, particulary for tie-ins. Flanged connections can withstand the full range of pressure requirements. Figure 4-8 illustrates a flanged steel pipe connection.

This bolted, mechanical joining method requires no special skills or equipment, although it is not very resource efficient. The cost of the flange itself makes it an expensive



where a = Socket diameter
L = Joint thickness
d = Socket depth
e = Centering shoulder depth
f = Centering shoulder

FIGURE 4-7

STANDARD BELL & SPIGOT JOINT

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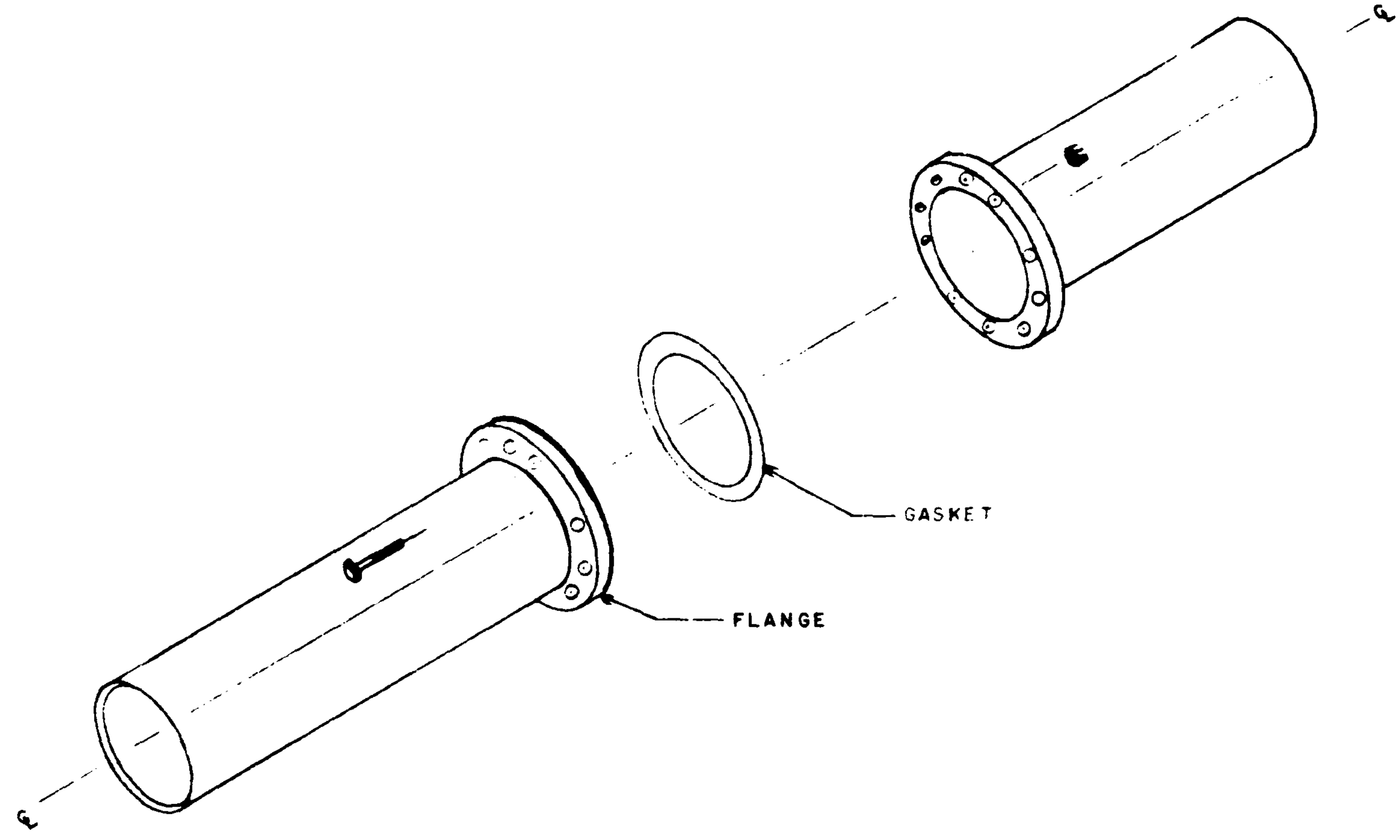

FIGURE 4-8	
FLANGED JOINT — STEEL PIPE	
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method of pipe joining, plus the flange must still be attached to the pipe. Once the flanges are attached to the pipe, joint make-up proceeds very fast from aligning to bolt tightening, particularly in the smaller sizes.

4.3.5 Collar/Gasket

Collar/gasket couplings encompass a wide assortment of mechanical joints which generally use a gasket in compression to form sealing capabilities. Historically, one type which has been used by the oil, gas, and water industry employs a metal sleeve which is flared at each end and has a doughnut-shaped gasket with a backup ring at each end. This compression-type coupling is illustrated in Figure 4-9. The gaskets and backup rings are placed over the ends of pipe. The pipes are inserted into the metal sleeve. The backup rings are bolted together which compresses the gasket into the annulus between the sleeve and pipe, thus pressure sealing the pipe joints. The pipe can be pulled from the coupling with a minimum axial load. A similar coupling is a ball-and-socket joint (see Figure 4-10) where one end of the pipe has a flared ball which fits into cupped socket of the joining end. This is used predominately on cast iron pipe.

Another type of coupling reduces the pull-out problem by employing a groove, cast or machined into each pipe end or transition piece. Ring gaskets are placed in the grooves. A split-ring bolted coupler is placed over the pipe ends. Bolting the coupler engages the grooved pipe ends and compresses the gaskets into the grooves which forms the seal.

These types of couplings are expensive although no skilled personnel or special tools are required. They are not commonly used on pipelines except in some special cases of low pressure tie-ins. They are generally available in the full ranges of pressures and temperatures.

4.3.6 Cold or Hot-Pour

Cold or hot-pour joints are generally limited to no-pressure applications, except a caulked, hot-poured lead joint as used on cast iron or wrought iron. These joints are used in conjunction with bell-and-spigot pipe ends. A cold-applied or hot-pour mastic compound is used to fill the void between the bell and the spigot connection. The mastic joint cannot tolerate any axial force. This joint is used almost exclusively with reinforced concrete pipe. It is not practical for underwater joints.

4.3.7 Adhesive bonding

Adhesive bonding is the most popular method of joining plastic pipe, except some thermosetting plastics such as HDPE.

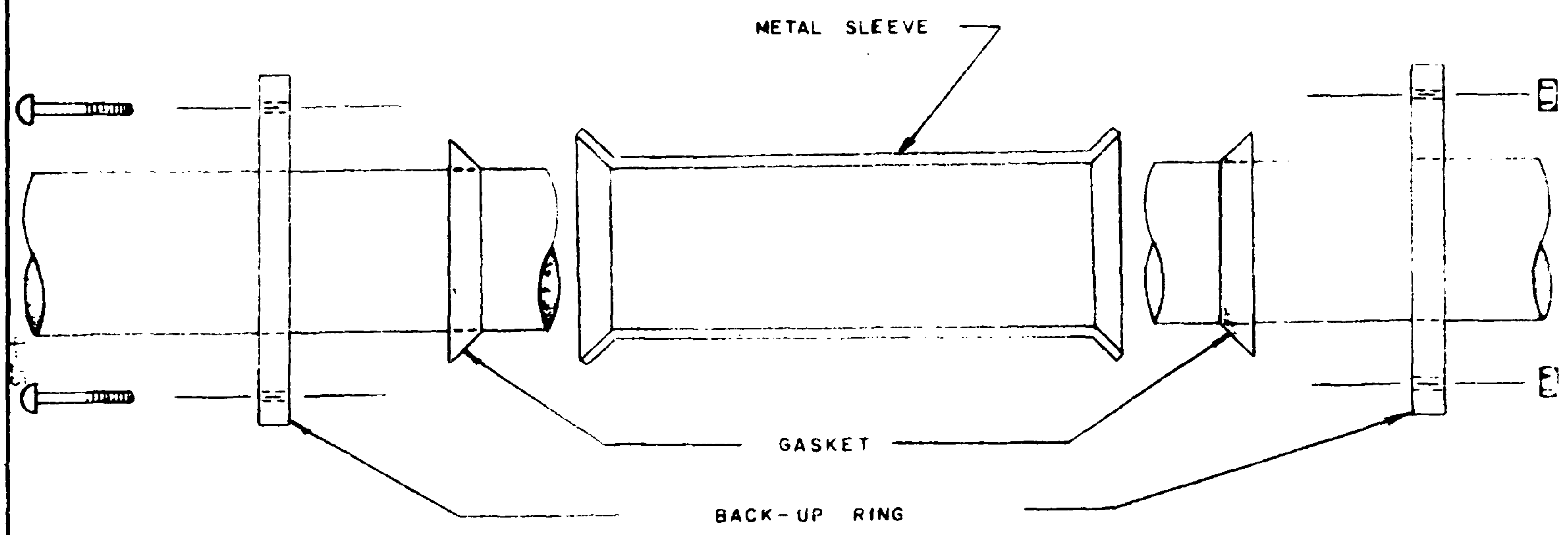

FIGURE 4-9
COMPRESSION COUPLING

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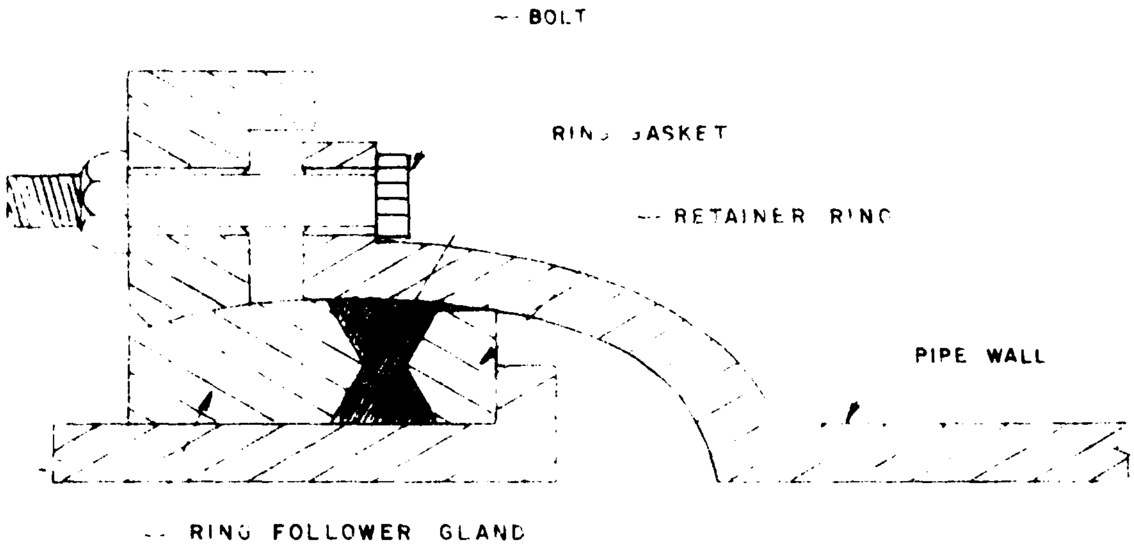

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FIGURE 4-10 BALL-AND-SOCKET JOINT	
DRAWN BY: J. DENTON	APPROVED: J.P.S.
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Adhesive bonding is used with either the glue-type joint with bell-and-spigot pipe or the built-up joint with butt-joined FRP. The bell-and-spigot glued joint is the more common joint for plastics. The built-up joint may be found on larger diameter FRP where a fiberglass matting saturated with epoxy resin is used to fabricate a joint collar. The curing time for an epoxy resin joint varies from 12 hours to several days. The bell-and-spigot glue joint can cure in several minutes to several hours depending on the type of plastic and the adhesive. The joint strength and sealing quality depends on the adhesive used and the quality of joint preparation and assembly.

Generally, adhesive bonding is an available technique for all pipe size ranges. It is acceptable for the same range of pressure and temperature as the pipe.

4.3.8 Butt fusion

Butt fusion is the technique usually used for joining HDPE pipe. With this joining method the ends of the two pipe sections are squarely machined by a special planing tool, softened by heating, and pressed together to form a butt fusion joint. This operation is illustrated in Figure 4-11. Curing of the joint consists only of cooling, and it is completed in a matter of minutes. The fusion joint is stronger than the pipe itself. Mechanical joints, such as steel or alloy flanges, can be fitted onto special molded pieces of HDPE pipe. A special heat fusion machine and skilled fusion technicians are required.

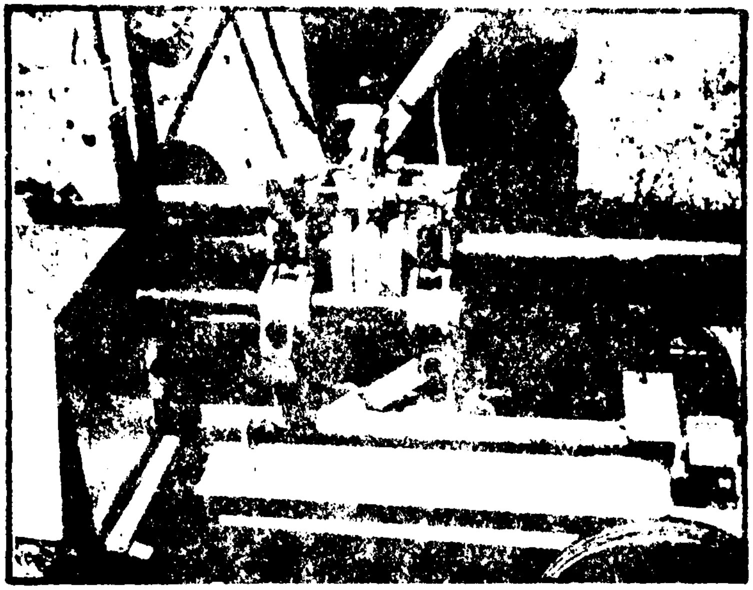
4.3.9 Swaged coupling

Swage couplings are used to form mechanical joints on metallic pipes. The pipe, with a bell-and-spigot or a metal sleeve, is deformed by a die under pressure or "swaged" to form the joint. An epoxy plastic may be applied before the joint is made-up by a swage coupling to assure a pressure tight joint. The joint is mechanical and does not rely on the epoxy sealant for strength.

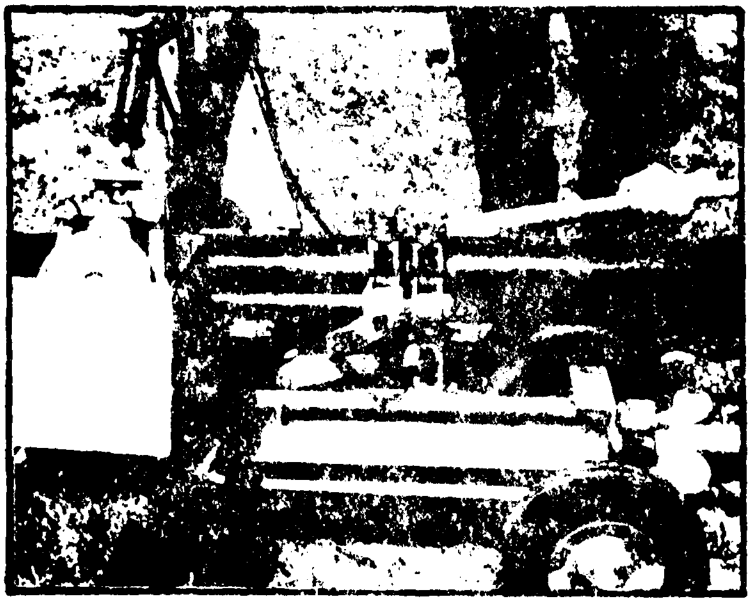
This method is generally limited to pipe 8 inches or less in diameter. It requires a special machine and skilled operators to prepare and effect the swage couple. It is a rapid and low cost method for joining small diameter, thin-wall pipe.

4.3.10 Buckle joint

Buckle joints are very similar to swaged couplings. They are used on metallic pipes to form a mechanical joint. The pipe is belled and a specially designed spigot is prepared. The spigot-end is designed to outwardly deform by buckling when sufficient axial force is applied. An epoxy sealant is applied to the spigot-end to act as a lubricant as well as a pressure sealant. The spigot-end is forced into the pipe bell by a hydraulic-powered machine. The pipe wall of the spigot buckles outward and engages the wall of the bell-end to form the joint. A cross section view of a buckle joint is shown in Figure 4-12.



HEATING ENDS OF PIPE WITH HEATING ELEMENT



FUSING JOINT BEFORE PIPE ENDS COOL

FIGURE 4-11	
BUTT FUSION OF HDPE*	
DRAWN [illegible]	APPROVED J.P.S
[illegible]	SCALE NONE
DMJM	8413-01-01

*FROM: "BUTT FUSION", DRISCOPIPE 7600 INDUSTRIAL PIPE, PHILLIPS DRISCOPIPE, INC., BROCHURE, P.5,7

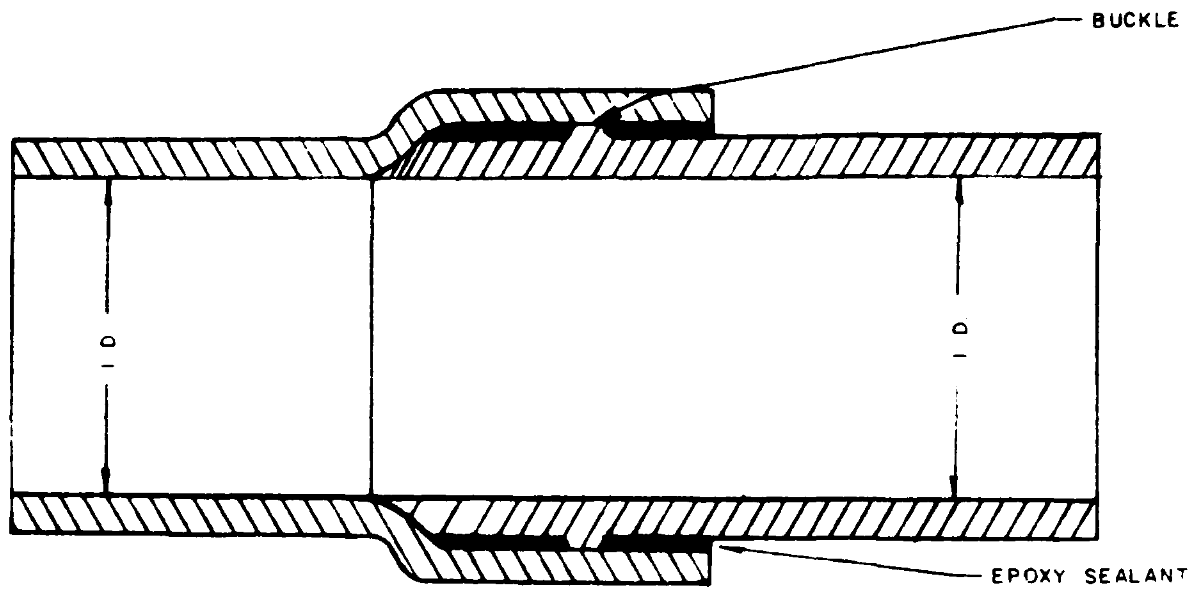


FIGURE 4-12 BUCKLE JOINT	
DRAWN BY J. DENTON	APPROVED: J P.S.
DATE FEB. 11, 1981	SCALE NONE
DMJM	8413-01-01

This method is limited to pipe sizes of about 6 inches in diameter or less. It is a rapid method of pipe assembly, but requires special machinary and skilled operators.

4.3.11 Quick coupling

Quick couplings are cam-locking, bell-and-spigot type couplings. The cam-locking device is manufactured on the female-end of the coupling, and a groove is manufactured on the male-end. The spigot is inserted into the bell and the locking device is engaged. The quick coupling may be connected to pipes by welding or screwed connections.

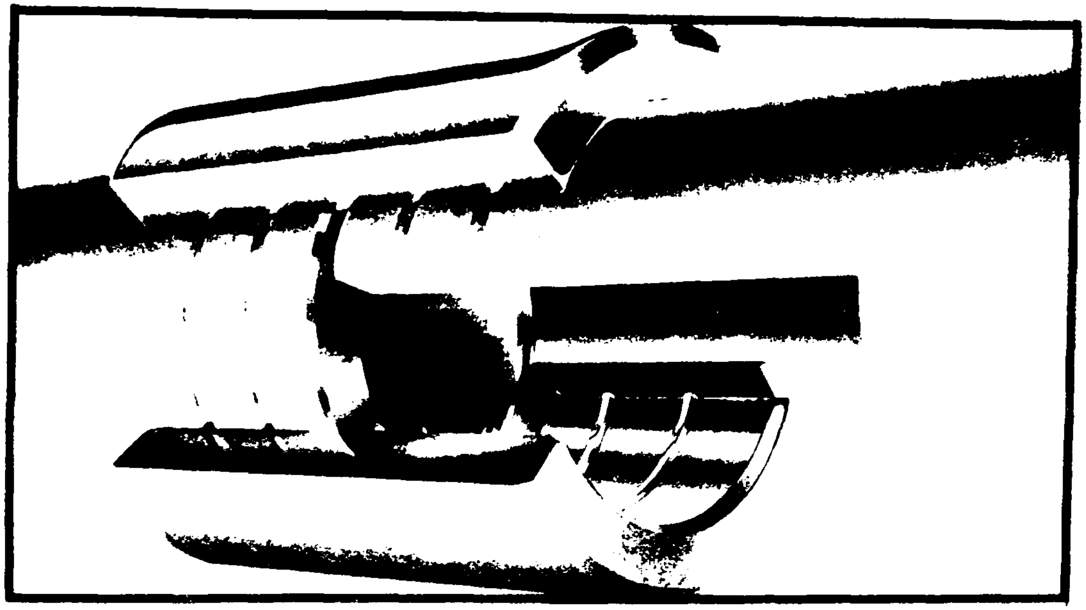
The quick coupling is limited in size to about 10 inches in diameter . It is a very rapid method of connection which requires no special tools and skilled personnel. Quick couplings are expensive, and are not recommended for permanent installations.

4.3.12 Cryofit and Betalloy

Cryofit and Betalloy mechanical couplings are presently used only for small diameter steel lines. They are state-of-the-art methods and are unique. With additional research and development these couplings may become available for larger pipe size ranges and may eventually be used with different pipe materials.

Both couplings use a sleeve-type connector made from a "shape-memory" alloy. These alloys are called "shape-memory" because of their ability to undergo a marked change in their physical properties at a temperature (known as the "transition temperature") as a result of a basic transformation in their crystalline structure.

Cryofit Subsea pipe couplings are hollow cylinders of a shape-memory alloy of titanium and nickel compounds. The bore of the cylinder contains several annular sealing lands and has an inside diameter approximately 3% smaller than the pipe to be joined. The coupling is cryogenically cooled and expanded to an inside diameter which is approximately 5% larger than the pipe's outside diameter. The coupling maintains this expanded shape as long as it is stored in liquid nitrogen below its transformation temperature. When the coupling is removed from its liquid nitrogen bath, slipped over the pipe ends to be joined, and allowed to warm to ambient temperature, it will attempt to shrink to its previous, unexpanded diameter. Since the pipe's outside diameter is larger than the unexpanded coupling bore diameter the coupling grips the pipe during the shrinking process. The high recovery forces of this alloy result in an interference fit between the pipe and the coupling with sealing pressures of up to 100,000 pounds per square inch (psi). Figure 4-13 shows a Cryofit Subsea coupling.



SEATED COUPLING WITH COUPLING PRESSURE LANDS
EMBEDDED IN PIPE SURFACE

FIGURE 4-13	
CRYOFIT COUPLING	
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DATE FEB 9, 198[illegible]	SCALE NONE
DMJM	8413-01-01

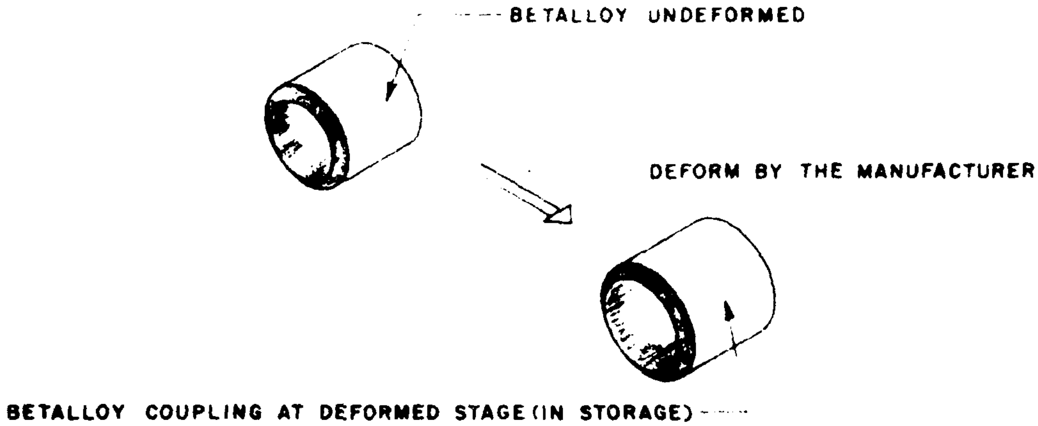
The coupling method is very fast, expensive, and available in sizes of 6 inches in diameter and less. Fittings must remain supercooled prior to use or they will shrink and become useless. A few special hand tools are required for handling the fitting, and personnel skilled in this method of assembly are necessary.

Betalloy couplings are hollow cylinders of a copper-based shape-memory alloy. The alloy is suitable for marine environments and is similar to naval brass in corrosion characteristics.

Betalloy deforms about 4% when cooled below its transformation temperature. Applying stress to the cylinder at this temperature sets the expanded state. When heated to a transformation temperature of about 100°F and then cooled the cylinder returns to its original, undeformed configuration. It forms a mechanical seal, like the Cryofit coupling, by shrinking and tightly gripping the pipe. Unlike Cryofit, Betalloy does not have to be cryogenically cooled to maintain its deformed state. No special tools are required except a heat source, such as a small torch. Coupling installation procedures are illustrated in Figure 4-14.

Betalloy is currently limited in size to a maximum of 1½ inches in diameter. Additional development is continuing to increase the size range.

IN THE FACTORY AND STORAGE



IN THE FIELD

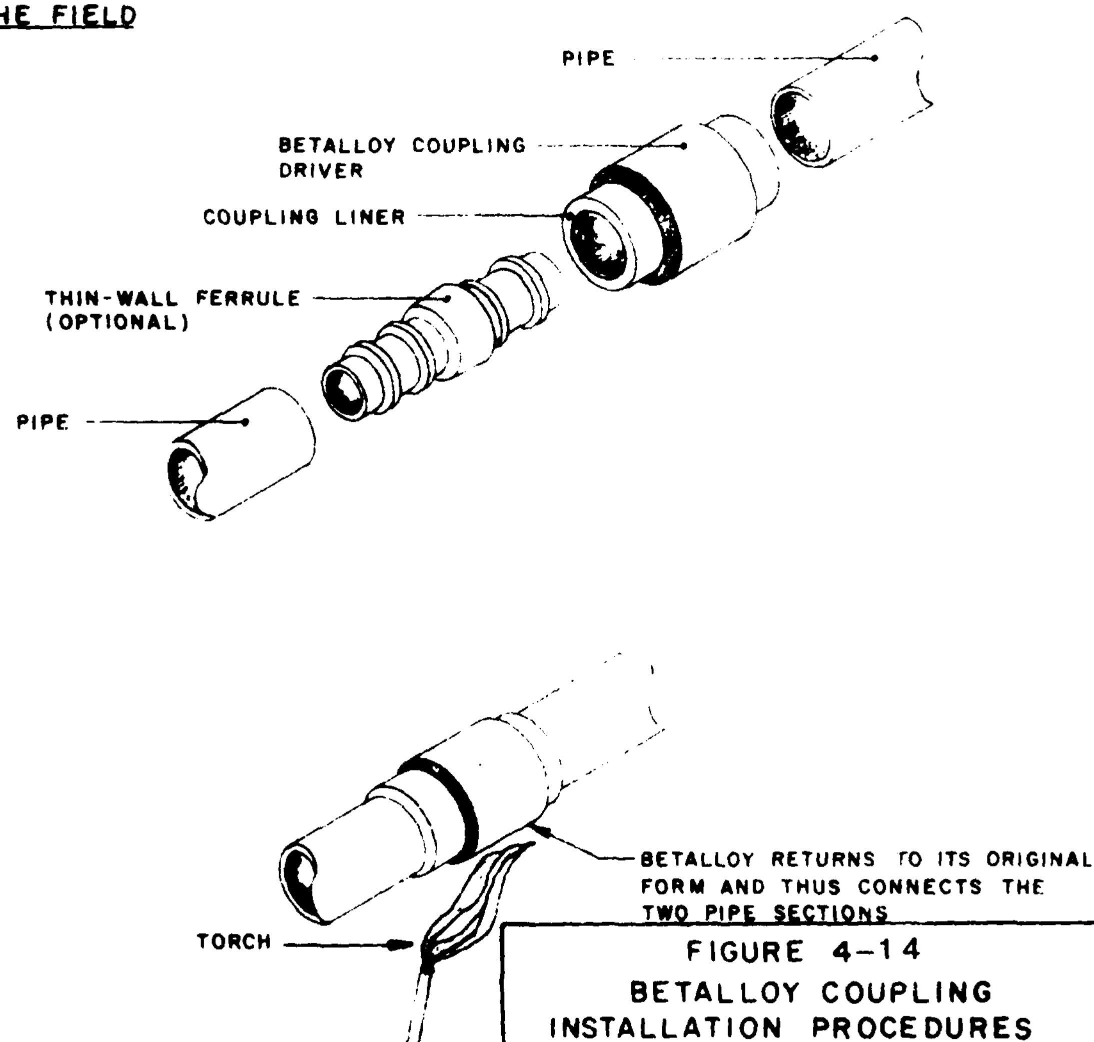


FIGURE 4-14
BETALLOY COUPLING
INSTALLATION PROCEDURES

DRAWN BY J. DENTON	APPROVED: J.P.S.
DATE: FEB. 9, 1981	SCALE: NONE
DMJM	8413-01-01

4.4 STABILIZATION METHODS

On-bottom stability is one of the most critical elements in the longevity of a pipeline. It includes the vertical and horizontal stability of the pipe and must consider the special conditions and loads on the pipeline during the installation phases and operational phase. Both buried and unburied marine pipelines or pipeline segments should be analyzed for stability.

On-bottom stability is a specialized area of pipeline design and is not defined as part of the study scope. However, the on-bottom stability of a pipeline does affect the selection of pipe material and construction method elements, so it deserves consideration. The general methods of providing on-bottom stability are presented as well as the forces and conditions which influence a pipeline. These sections are brief and present a general overview. Should the on-bottom stability technique influence a given method of installation, the nature and extent of the affect will be noted.

Stability is normally attained by trenching, adding extra weight, installing mechanical anchors, or a combination of these methods.

4.4.1 Trenching

Trenching effectively lowers the pipeline below the path of the horizontal current forces which tend to move the pipeline. Natural sediment transport will often provide the necessary backfill and additional weight. Prepared backfill can also be used. A typical pipeline trench cross section is illustrated in Figure 4-15. Trenching as applied to a specific method of construction will be discussed in the chapter on construction methods. This is a viable technique for providing pipeline stability.

4.4.2 Weighting

Weighting can be done either by machine applying or by forming-and-pouring a continuous reinforced concrete weight coating to the pipe (see Figure 4-16), by clamping on intermediate weights, or by piling backfill or heavy coarse stones over the pipeline. Continuous concrete weight coating densities can be varied between about 140 to 190 pounds per cubic foot to achieve an optimum balance between weight coating thickness and overall diameter. Continuous concrete weight coating is the preferred method of weighting steel pipe but is limited to a maximum total thickness of 5½ to 6 inches.

Intermediate weights can either be bolt-on weights attached before the pipeline is installed (shown in Figure 4-17) or saddle-type set-on weights installed after the pipeline is inplace (see Figure 4-18). Although this type of weight is sometimes easier to fabricate and install than continuous concrete

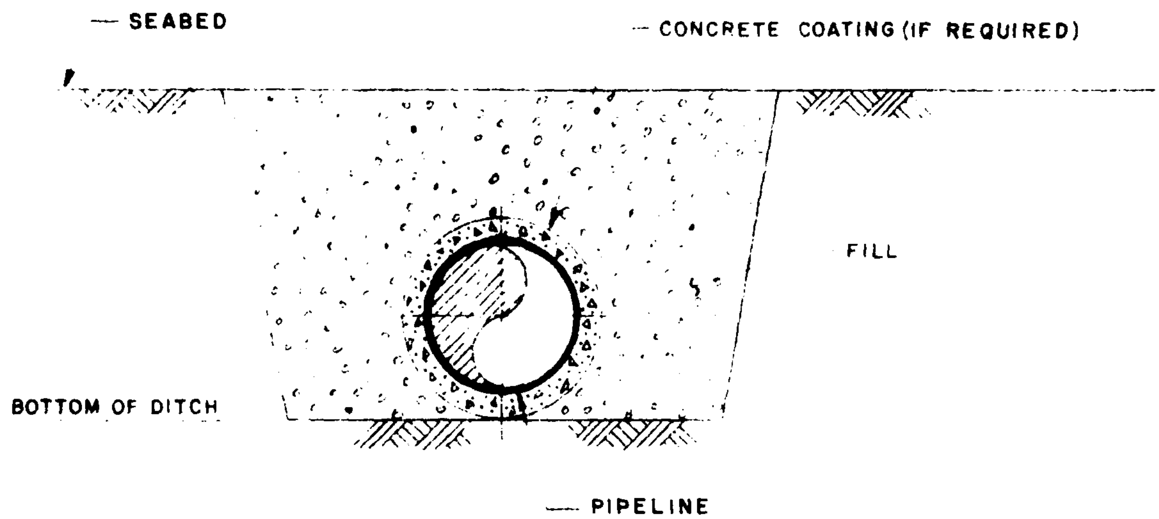


FIGURE 4-15 TYPICAL PIPELINE TRENCH CROSS SECTION	
DRAWN BY . J DENTON	APPROVED : J.P.S
DATE DEC. 2, 1980	SCALE : NONE
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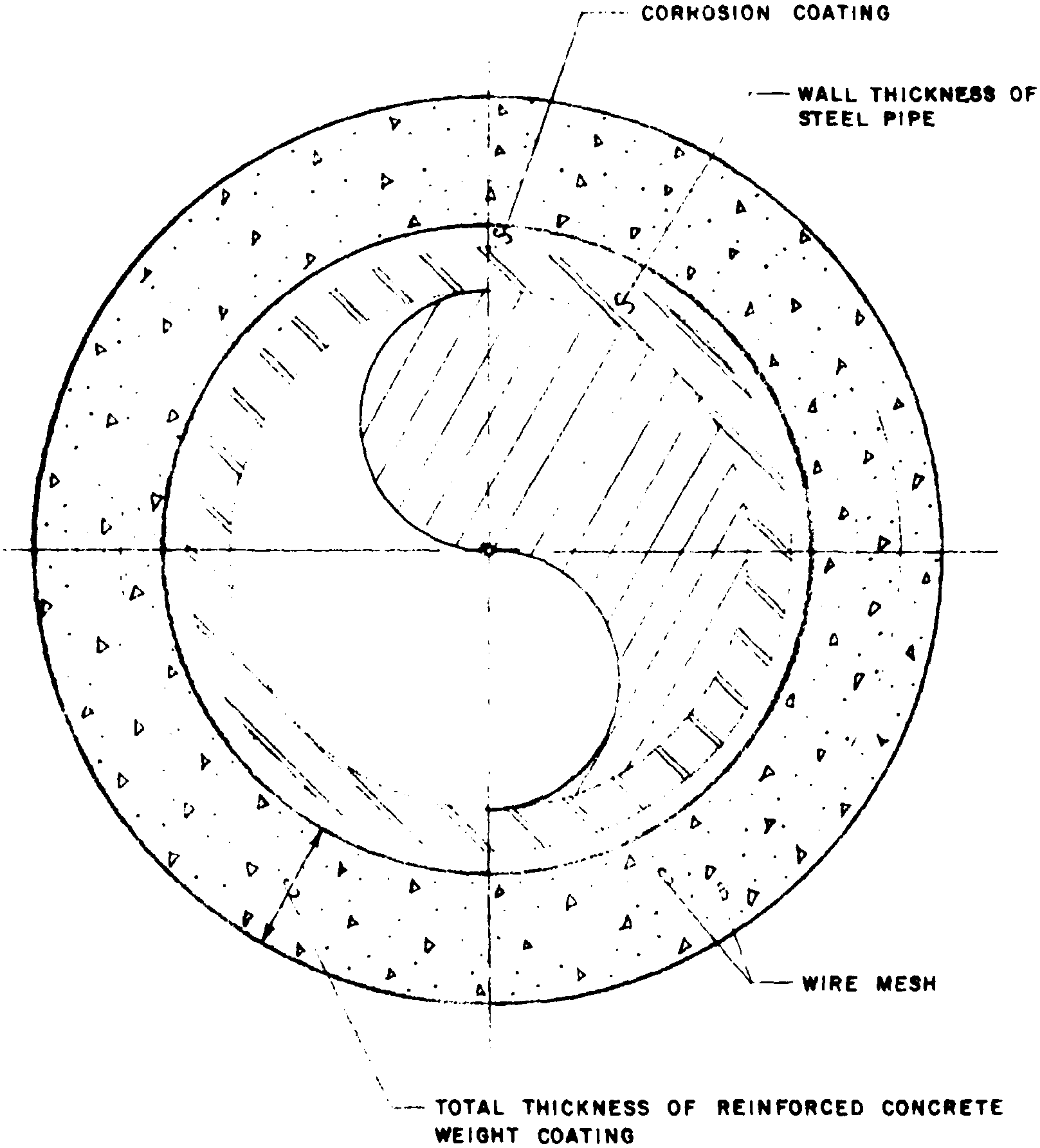

FIGURE 4-16 TYPICAL CROSS SECTION CONCRETE WEIGHT COATING	
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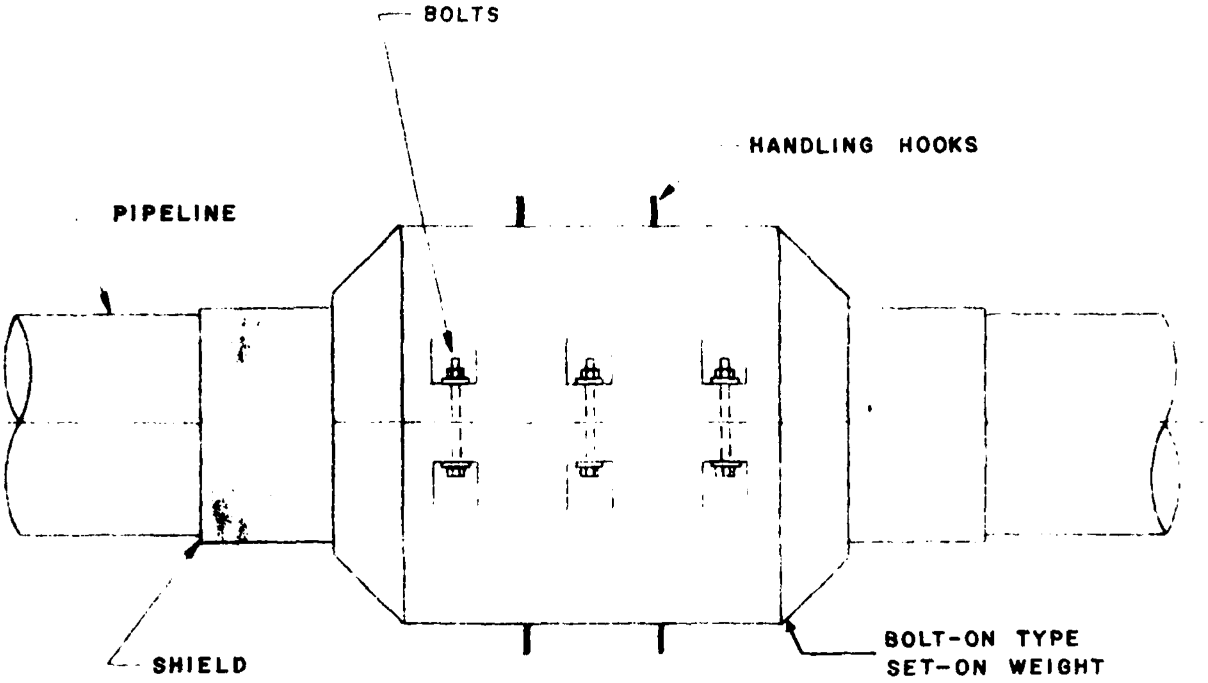

FIGURE 4-17 BOLT-ON TYPE SET-ON WEIGHT	
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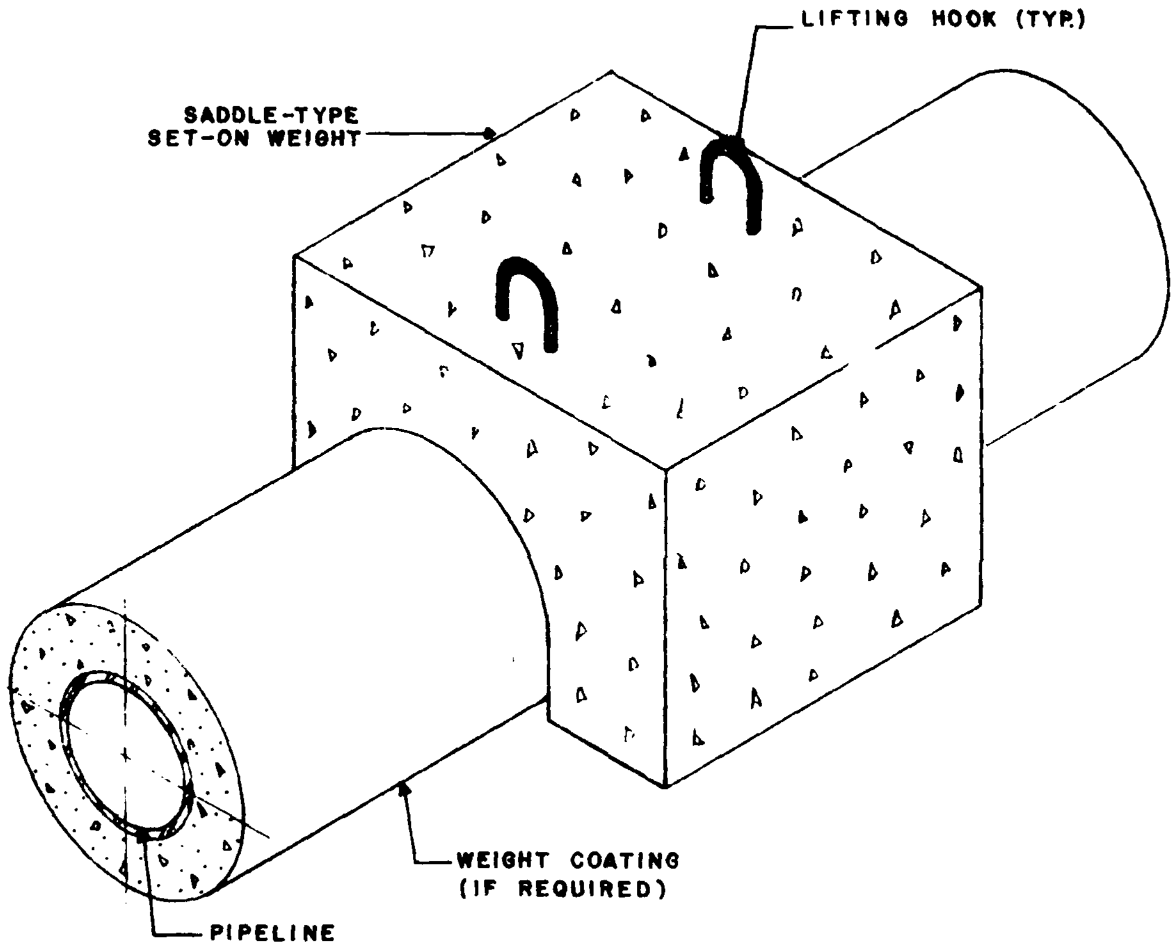

FIGURE 4-18 TYPICAL SADDLE-TYPE SET-ON WEIGHTS	
DRAWN BY: J. DENTON	APPROVED: J.P.S.
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coating, it has several disadvantages. On fine sediment bottoms these intermittant large cross section shapes cause scouring of the seabed. Additionally, the pipeline installation is often hampered by the large "bulges" on the line.

When piling gravel, stone, or riprap over pipelines, care must be taken to prevent damage to the pipeline coating. Stone size must be large enough to prevent stone movement during the maximum design sea currents. Figure 4-19 illustrates a typical unburied pipeline cross section with backfill and riprap placed over it.

4.3.3 Mechanical anchors

Mechanical anchors are usually steel and are not designed to add weight. They maintain a hold-down force on the pipe when properly installed in the soil. These may be auger-type or expanding-type mechanical anchors.

Auger-type anchors are the most commonly used type of mechanical anchor. It consists of steel plate shaped in a sprial helix (like an auger) and attached on the end of a long steel rod. The other end of the rod is threaded for attachment to a hold-down strap on the pipeline. This system consists of two anchors and a strap shaped to fit the pipeline. Installation consists of installing an anchor on each side of the pipeline and attaching the strap to both anchors. The formed strap fits snugly over the pipeline securing it in place. The anchors and strap are usually galvanized to retard corrosion and failure. Small sacraficial anodes can be attached to each anchor to increase corrosion protection (see Figure 4-20).

Expanding-type mechanical anchors are used in the same manner as the auger-type. The anchor rod has flukes on one end that are hinged in such a way as to expand outward from the rod and engage the soil. Most are expanded by turning the threaded anchor rod which runs through a nut in the center of the flukes. As the rod is turned, the flukes are pushed and expanded by the nut jamming against a cam plate, which forces the flukes outward (see Figure 4-21). The expanding anchor is installed in two ways. One method is to bore a hole to the desired depth and place the anchor in the hole. The anchor is then expanded. The second method is to apply sufficient axial force on the anchor to push it into the seabed. When forced to the desired depth, the anchor is expanded. In areas where the soil has low shear strength, the expanding anchor can be made with tandem flukes. This increases the anchor area without sacrificing easy installation. The largest drawback to mechanical anchors is reliability. Mechanical anchors are seldom tested after installation, and whether they achieve sufficient holding capacity is usually in question.

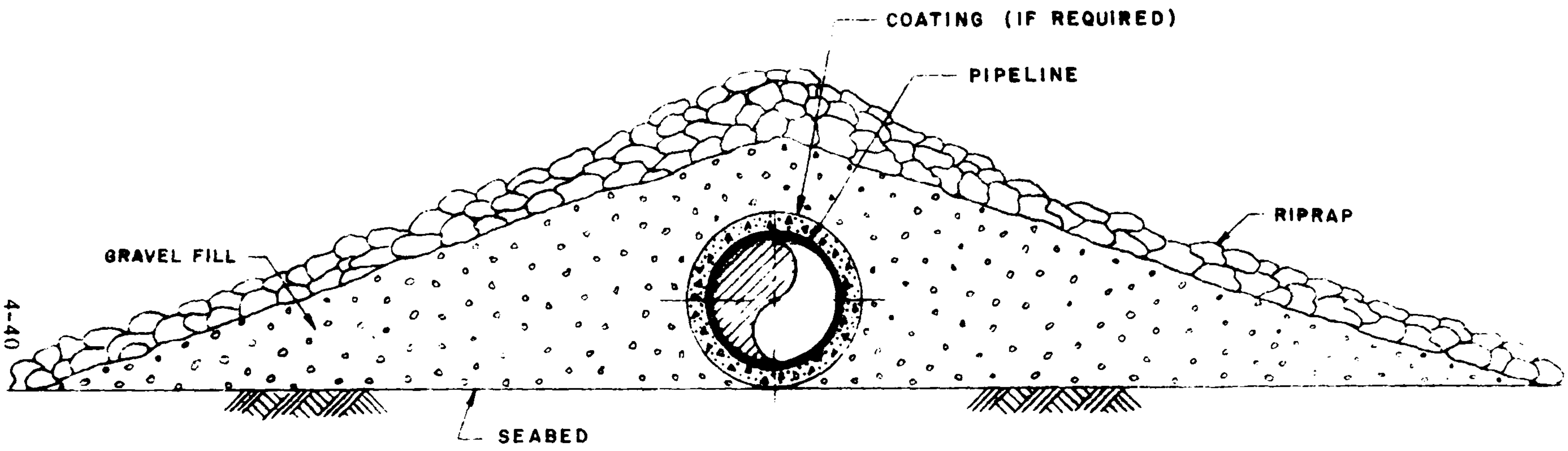

FIGURE 4-19	
TYPICAL RIPRAPPED UNBURIED PIPELINE CROSS SECTION	
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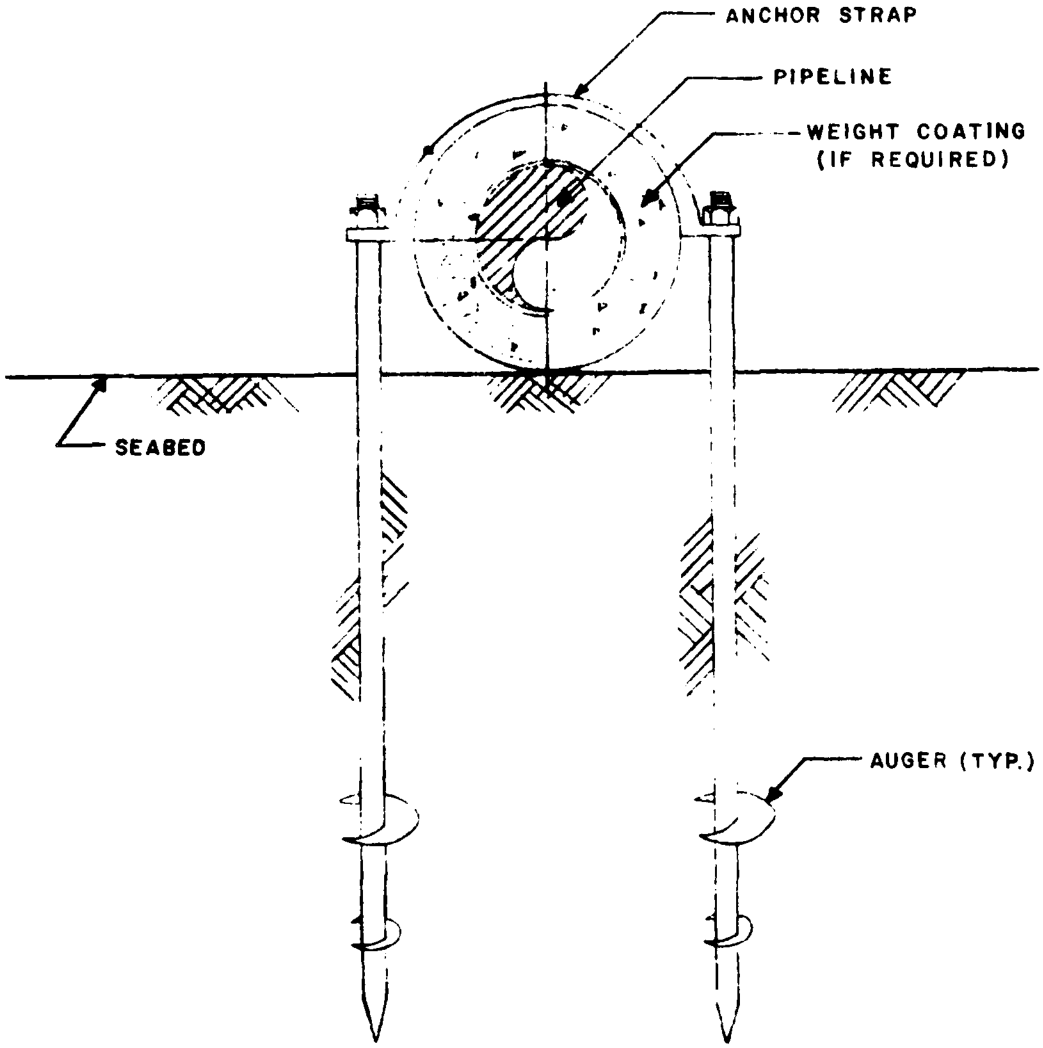

FIGURE 4-20 AUGER-TYPE MECHANICAL ANCHOR	
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DATE: FEB 10, 1981	SCALE: NONE
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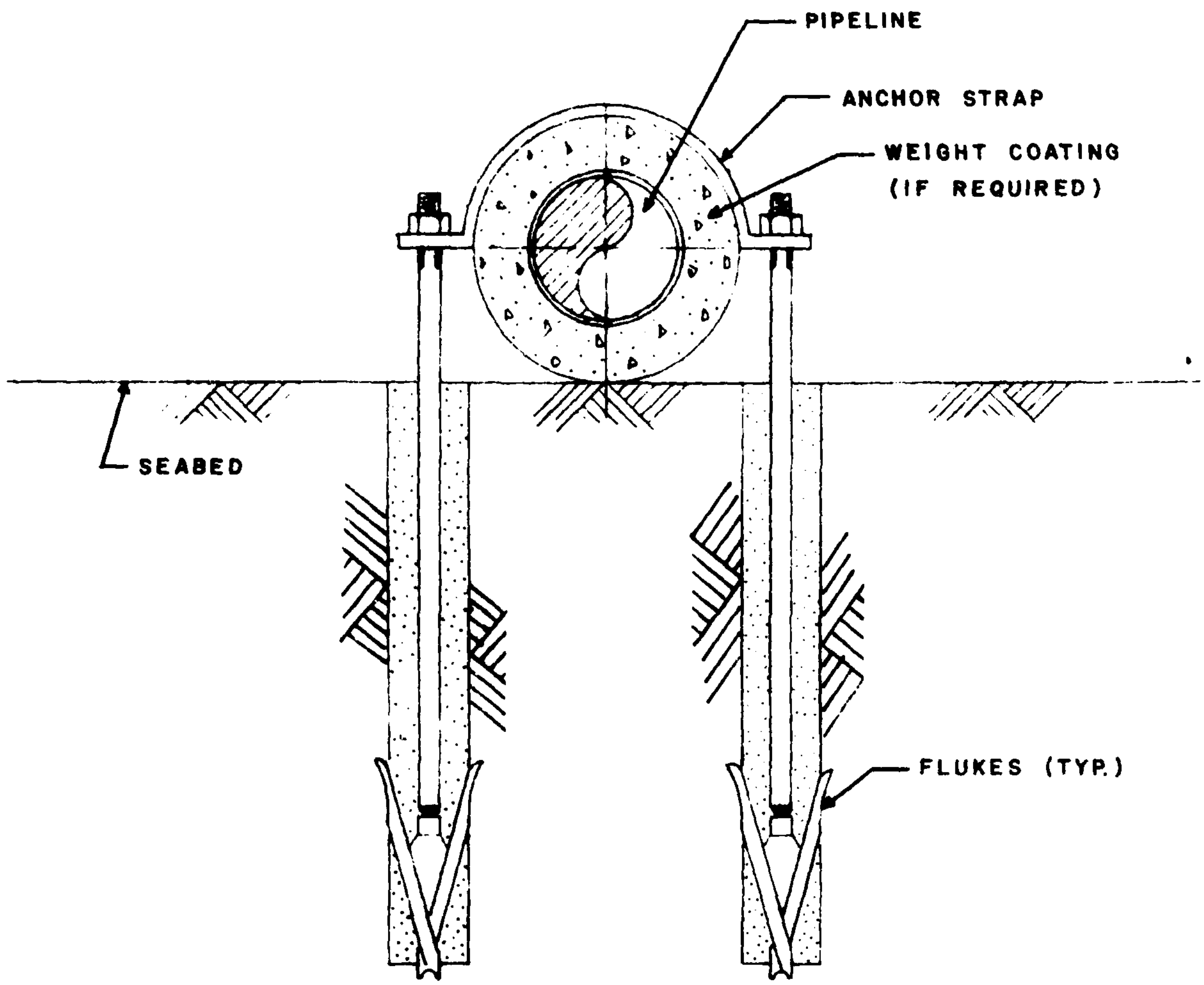


FIGURE 4-21 EXPANDING-TYPE MECHANICAL ANCHOR	
DRAWN BY: J. DENTON	APPROVED: J. P. S
DATE DEC. 8, 1980	SCALE: NONE
DMJM	8413-01-01

If rock or coral bottoms are present it is possible to drill and grout the anchors in place. A drilling unit must be mobilized, usually at a large expense.

4.5 FORCES ACTING ON MARINE PIPELINES

In general, the forces acting on pipelines depend on its geographic location (exposure to waves and sea currents), whether or not it is in a trench, and the soil or geologic conditions.

Soil forces to be considered in pipeline design include soil resistance to sliding (or frictional resistance between the pipe and soil), bearing capacity, liquefaction potential, and potential for sliding failure (or slope instability). The last element is characteristic of delta areas where mud slides are frequent. Most pipelines are in locations where the other factors are dominant.

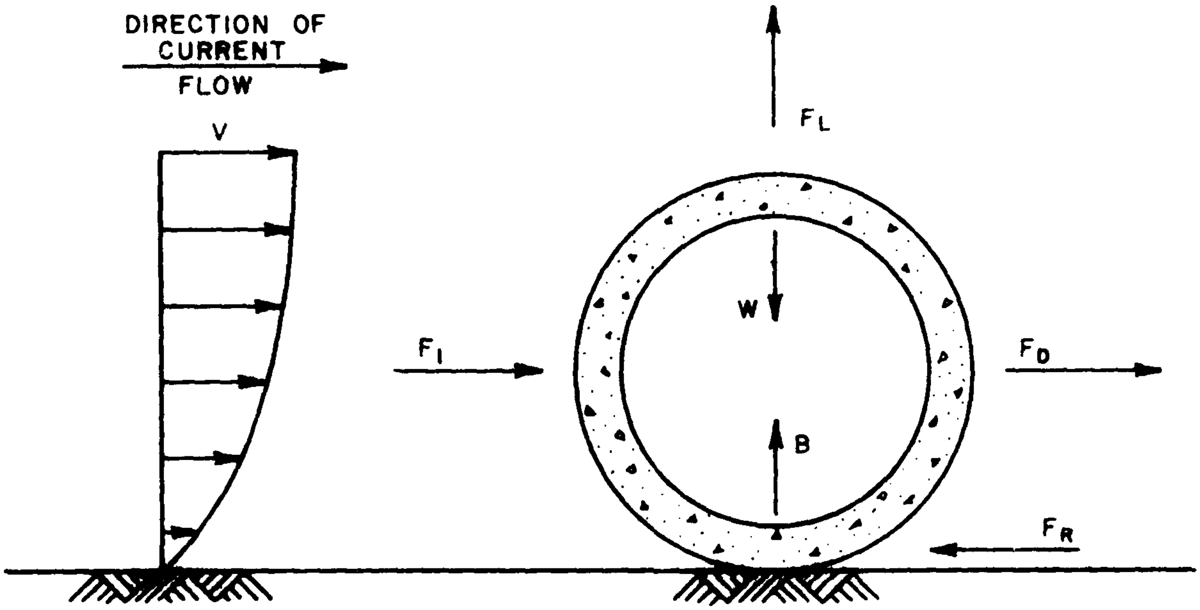
Six major forces act on an unburied underwater pipeline resting on a seabed. They are submerged weight, buoyancy, lift, drag, frictional resistance, and wave inertia. Figure 4-22 illustrates these forces and their relative directions.

The submerged weight of a pipeline may be varied by changing its wall thickness, by changing the type or thickness of the coating material, or by adding auxilliary weights. The buoyancy of a pipeline equals the weight of the fluid it displaces. The fluid may be fresh water, sea water, silt, or liquified soil in some instances. Lift is exerted on a pipeline when a current flows around it. This force arises from the non-uniform flow pattern of the fluid flow where the fluid velocity across the top is greater than across the bottom and causes a lower pressure region. Drag is due to a pressure difference between the upstream side and downstream side of the pipeline. The pressure is higher on the front area than on the back area which is in the wake, a region of reduced energy. Frictional resistance is the result of the force between the pipeline and the supporting material or seabed. This force contains all the components that resist horizontal movement of the pipe relative to the supporting material.

The inertia force is due to wave action. It is the resistance to an accelerating fluid flow past the pipeline in excess of the lift and drag forces. This force is caused by the additional acceleration required to move the fluid past the pipeline.

Vertical instability of an unburied pipeline occurs when it floats to the water's surface or when it sinks substantially into a soft bottom sediment exceeding the design stress limits. As shown in Figure 4-23, one of four conditions will occur when a pipeline is laid on the seabed. It will either:

a) Float to the surface due to buoyancy.
b) Lie on top of the seabed.



where: F_I = Inertial Force

F_D = Drag Force

F_L = Lift Force

F_R = Soil Resistive Force

W = Weight

B = Buoyancy

FIGURE 4-22 FORCES ACTING ON UNBURIED UNDERWATER PIPELINE	
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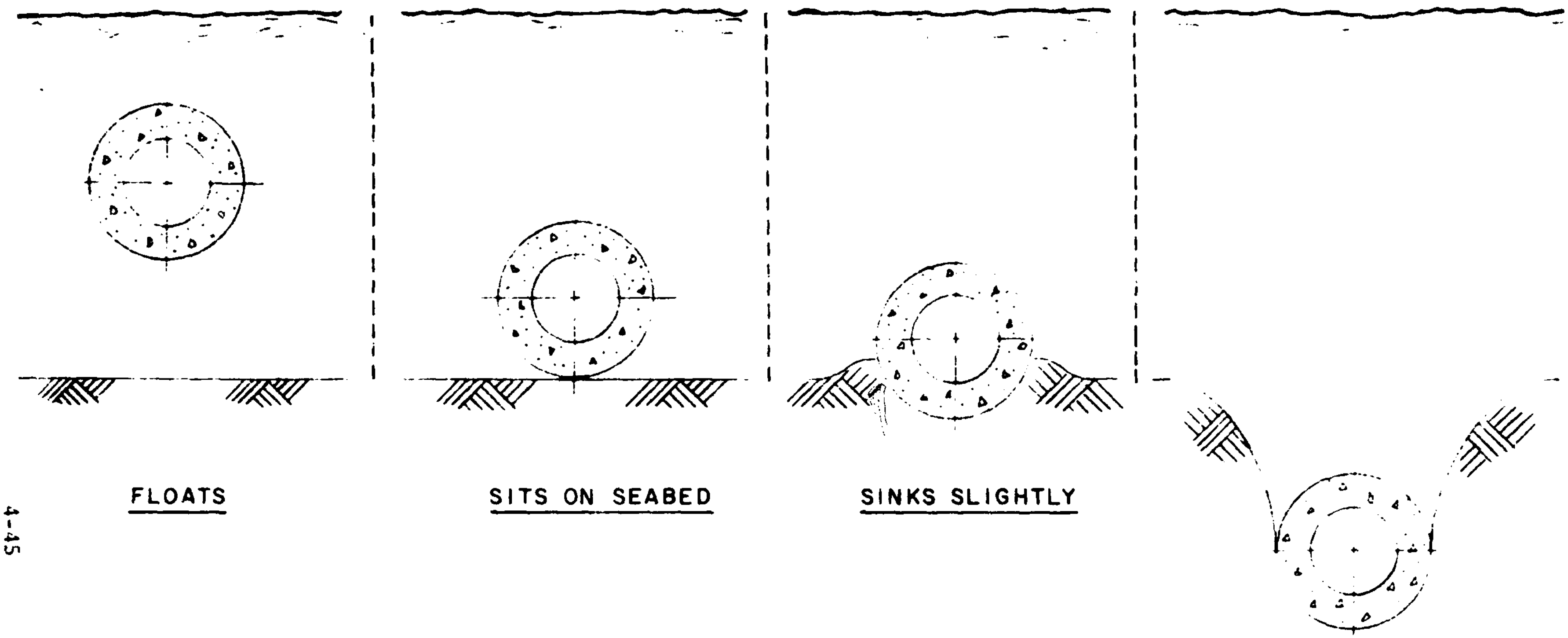


FIGURE 4-23
POSSIBLE RESULTS OF LAYING A PIPELINE ON THE SEABED

DRAWN BY: J. DENTON	APPROVED: J.P.S.
DATE DEC 2, 1980	SCALE: NONE
DMJM	8413-01-01

c) Sink slightly into the bottom until the bearing area of the pipe is sufficient to provide support.
d) Sink substantially into the soft bottom sediment.

Settling of a pipeline into soft sediment is essentially a soil bearing failure. Pipeline failure or damage is unusual but it has happened and the possibility should be considered in design. Even if the pipeline is not damaged, a settling of 10 to 20 feet into soft mud would severely hinder maintenance or repair. Soil survey data is used to predict the depths to which a pipeline will sink into the seabed. If the seabed consists mostly of sand, adequate bearing capacity is usually assumed since sand will normally support the anticipated loads. Exceptions to this are situations where sand may become "quick", or liquified, due to an upward flow of water or seismic shock.

4.6 EXTERNAL COATINGS AND INTERNAL LININGS FOR PIPELINES

4.6.1 External Coatings

External coatings are not normally required for concrete, cast iron, or plastic pipe. Steel pipe is almost always coated externally and sometimes lined internally with a corrosion prevention coating depending on the transported fluid. Steel is normally cathodically protected to prevent galvanic corrosion.

Two types of external coatings are included in the design of most steel pipelines - a corrosion prevention coating and a weight coating. The purpose of the corrosion coating is to form a barrier between the sea water (the electrolyte) and the steel. Weight coatings are used to make the pipeline heavy enough to sink and remain stable on the seabed during storms and tidal movements. Weight coating has the additional advantage of protecting the external corrosion coating from damage during handling, transportion, and installation. Pipelines with diameters less than 12 inches are often installed with only a corrosion prevention coating. Although larger diameter steel lines occasionally are installed with no concrete weight coating, this will usually result in excessive damage to the corrosion prevention coating.

Most types of corrosion prevention coatings are suitable for marine pipeline applications. However, tape coatings are not normally used offshore or in areas where the pipe is submerged. Weight coating application damages tape coatings. Experience indicates that continuous submersion in water can eventually cause tapes to disbond from the pipe.
Thin film epoxy coatings are occasionally used but they are expensive. The most popular coating materials are:

a) Coal tar enamel.
b) Asphalt enamel.
c) Polyethylene or Polypropylene.

Coal tar enamel and asphalt enamel coatings are the most popular and have proven their ability to withstand the marine environment. These are normally 3/32 inch thick and overlaid with a felt outerwrap. Surface preparation includes sand or shot blasting to provide a clean surface. A high quality primer is used to insure a good bond between the pipe metal and enamel coating.

Polyethylene and polypropylene are normally used as tube-like jackets around the pipe with the annulus between jacket and pipe filled with mastic. An extrusion process is used to apply the coating. This type of coating is generally limited to smaller pipeline diameters which require no weight coating. Concrete weight coatings are not applied over such coatings. Field joints are usually coated with heat sensitive tapes or heat shrinkable sleeves.

Coatings are normally applied in a permanent coating yard well in advance of construction. This is done in order to protect the pipe from oxidation type corrosion during storage, and to prevent delays during construction due to coating yard breakdowns. As steel pipe is usually welded, about 6 to 8 inches at each end of the pipe length are left uncoated. After welding, this uncoated area must be wire brush cleaned, primed, and coated with materials compatible with the coating previously applied. It is more difficult to get a good quality coating system at the joints due to field type conditions.

Coating integrity can be inspected with a portable, electrical resistance monitor, commonly called a "jeep" or "holiday detector". A flexible spring completely encircling the pipe is pulled over the entire length of pipe. Resistance levels on the machine are adjustable to allow for different types and thicknesses of coating. If a hole in the coating (often called a "holiday") is found, the detector will alarm at the exact location. The holiday is then repaired before pipe installation continues.

4.6.2 Internal Linings

Internal linings are not required for non-corrosive pipe materials, such as plastic or cast iron. Steel may be lined with a corrosion prevention coating. A wide range of coating material, can be used, including baked-on epoxy or other resins and paints. The most commonly used linings for water and wastewater services are coal tar enamel, coal tar epoxy, and cement mortar. A primary reason for the popularity of these materials is economics.

Other internal lining materials which have been used in applications such as potable water, oil, and gas include:

a) Zinc silicate-epoxy (potable water).
b) Polyamide cured epoxy (oil and gas).

c) Epoxy-phenolic (oil and gas).
d) Polyurethane (abrasive slurries).

These linings are used where special conditions warrant the extra expenditure. Some of these special conditions are water quality, highly corrosive or abrasive fluids, and improvements to fluid flow efficiencies.

During welding operations the lining will be "burned-back" or charred for 2 to 3 inches. This area may be cleaned and recoated using a compatible primer and coating material. On large pipelines this presents few problems since a man can crawl into the pipe for joint coating. On smaller lines an *automatic cleaning and coating machine* is sometimes used but its results are not very consistent. Sometimes the welded joint area is left uncoated in smaller lines.

CHAPTER 5

CLASSIFICATION OF INSTALLATION METHODS

5.0 METHODS CLASSIFICATION

After examining the various installation methods identified in the early stages of the study, the following classification system was developed:

a) Onshore Assembly, Surface Connection.
b) Onshore Assembly, Seabed Connection.
c) Offshore Assembly, Surface Connection.
d) Offshore Assembly, Seabed Connection.

Assembly means the location where the majority of the pipe lengths are joined together. Several installation methods involve the assembly (joining) of pipe sections into long "pipe strings" at one location, transportation of the pipe strings to the job site, and making a final connection of the pipe strings along the pipeline route. This final connection can be done on the water surface or on the seabed by divers, hence, the second part of the classification designation.

Assembly of the pipe can be done either onshore or offshore. Furthermore this can be either at or near the pipeline route or at a remote site. Onshore assembly, as used in this report, includes instances where the joints are connected on land either on-site or at a plant/fabrication yard which is removed from the pipeline installation site. Offshore assembly encompasses all instances where the pipe joints are not assembled on land. This includes assembly on the water's surface and below the surface (for example lay barge and seabed connection methods respectively).

Surface connection of the assembled pipe strings includes both onshore connections where the completed pipe strings are joined on land and offshore connections which are at or above the water's surface. Seabed connections are done below the water's surface with divers.

The classification system listed above was chosen for the following reasons:

a) The three primary activities common to all nearshore pipeline installation methods (assembly, connection, laying) are included in the system.
b) All methods can be assigned to one of these classifications.
c) It provides a relatively easy analogy with the UCT/NMCB capability making the final analysis easier.

Only the state-of-the-art methods were formally classified. Conceptual methods considered were evaluated primarily on the basis of their potential for use by the UCT/NMCB. Those methods finally selected as having potential are discussed in Chapter 8.

CHAPTER 6

STATE-OF-THE-ART PIPELINE INSTALLATION METHODS

6.0 GENERAL

For the purposes of this study, state-of-the-art installation methods are defined as those construction methods which have been proven by successful field experience. This means that pipelines had been successfully installed by the method.

A comprehensive literature search was made to determine which marine pipeline construction methods would fall in this category. Literature sources included the material furnished by the study sponsors, the DMJM and university libraries, National Technical Information Service listings, and those sources listed on several commercial data bases such as the Engineering Index. Appendix A entitled Pipeline Installation References, contains a listing of pertinent articles obtained during the search. In areas where questions existed, the DMJM team directly contacted industry representatives to obtain information on viable solutions.

The methods selected as state-of-the-art were categorized in accordance with the classification system described in Chapter 5 and are discussed in subsequent paragraphs. Rather than prepare a long detailed list by giving names to numerous method variations, subsequent paragraphs discuss the general method concepts. Pertinent variations are discussed within each broad concept. For example, using the pull method, pipelines can be pulled from shore to seaward or from the sea toward the shore. Fabrication can be done either onshore, or offshore on a floating work platform. Pipelines have been pulled along the seabed, slightly off-bottom, and on the surface of the water. Yet the basic concept of installation is "pulling", so method variations are discussed under "Pull Method".

6.1 ONSHORE ASSEMBLY, SURFACE CONNECTION

6.1.1 Pull Method

This method involves pulling the assembled pipeline into place along or near the exact final route, sometimes over a previously prepared seabed. The pulling force is usually supplied by a large winch, although tugboats have been used. A wire rope is paid out along the route, connected to the leading end of the pipe string, and winched-in to pull the pipe along. Pipelines have been successfully pulled from shore and toward shore. If the line is pulled toward shore, assembly of the pipe joints is done on a floating barge. If pulled from shore, pipe assembly is done onshore, and the winch is located offshore on a securely anchored winch barge. Whenever possible, it is wise to fabricate onshore. Long lengths can be welded or otherwise joined together in a large staging area unaffected by offshore sea conditions. Fabrication of the pipeline on an offshore barge is more time consuming and difficult.

Pipe can be pulled along the route at any of three basic elevations - on-bottom, off-bottom (near the bottom but not in contact), and surface. An on-bottom pull is preferred because the lateral stability is greatest, hence less danger of the pipeline being swept aside and severely damaged by currents. On-bottom pull requires the most pulling force due to the frictional sliding resistance of the pipeline on the sea bottom. A surface pull is the most risky pull method.

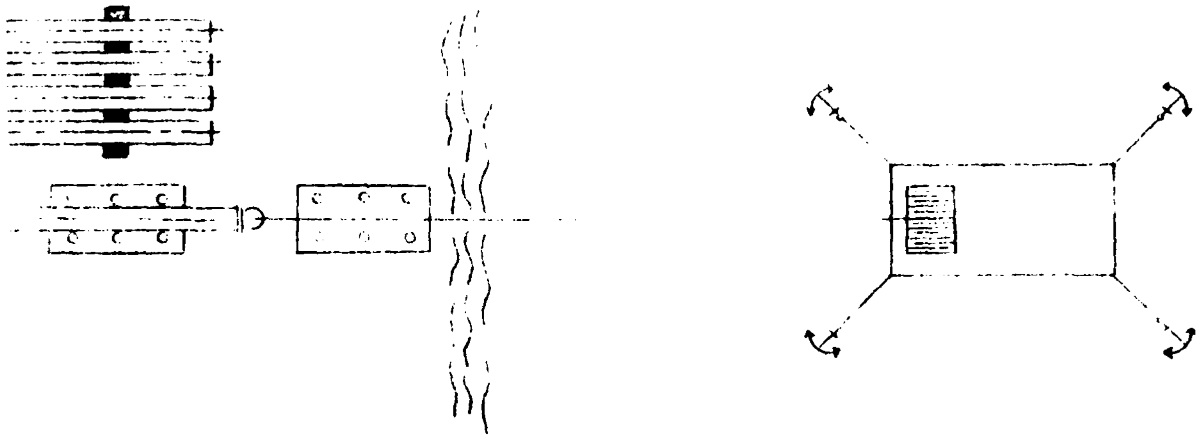
Figures 6-1A through 6-1D illustrate a typical bottom pull sequence. Figures 6-2A and 6-2B illustrate a typical off-bottom pull using float devices. A configuration of an off-bottom pull using the float-and-chain technique is shown in Figure 6-3A. Floats hold the pipeline off-bottom and the chains add sufficient weight to prevent the pipeline from floating to the surface but not so much that the pipeline drags on the seabed. An off-bottom pulling sled configuration is shown in Figure 6-3B. The off-bottom pull method is used when excessive damage to either the pipeline or the pipe coating would occur by dragging the pipe-line on the seabed.

A surface pull will be the same as other pull methods except the pipe will be floating on or near the surface.

On most projects, the UCT/NMCB will not have a large, fully equipped pipe fabrication barge available. Since most pull method projects have been pulled from shore to offshore, it is more practical to discuss the pull method in terms of shore fabrication and a pulling point offshore. The remainder of this discussion will assume this pull method configuration.

Sequential steps of the Pull Method include:

a) Mobilization:
   1. Personnel
   2. Equipment
   3. Materials
b) Equipment Rig-Up.
c) Site Preparation:
   1. Onshore
   2. Offshore
d) Construction:
   1. String pipe for joining
   2. Join pipe to form pipe strings
   3. Inspect and test pipe joints
   4. Field coat pipe joints (as applicable)
   5. Prepare pipe launchway/ramp
   6. Pretrench ditch (as applicable)
   7. Attach pulling line to pipe string on launchway
   8. Position pull barge (for offshore pull)
   9. Pull pipe string seaward

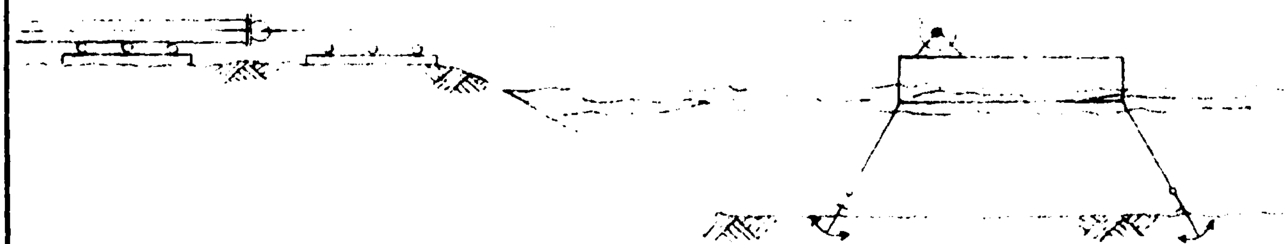


— STRING PIPE FOR JOINING .

— JOIN, INSPECT, TEST, AND FIELD COAT JOINTS.

— PREPARE LAUNCHWAY AND PULL BARGE.

— PREPARE DITCH (AS APPLICABLE).



— POSITION BARGE AND ATTACH PULLING LINE TO PIPE STRING ON LAUNCHWAY.

— PULL INITIAL PIPE STRING SEAWARD.

FIGURE 6-1A TYPICAL BOTTOM PULL SEQUENCE	
DRAWN BY: M. RICH	APPROVED: J.P.S.
DATE: APRIL 15, 1981	SCALE: NONE
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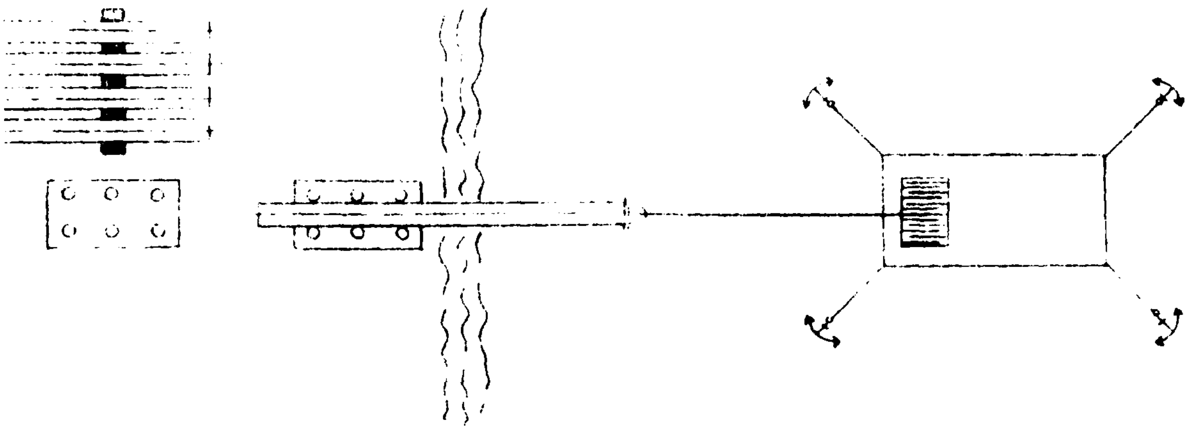

— STOP INITIAL PULL WHEN PIPE STRING IS AT END OF LAUNCHWAY.

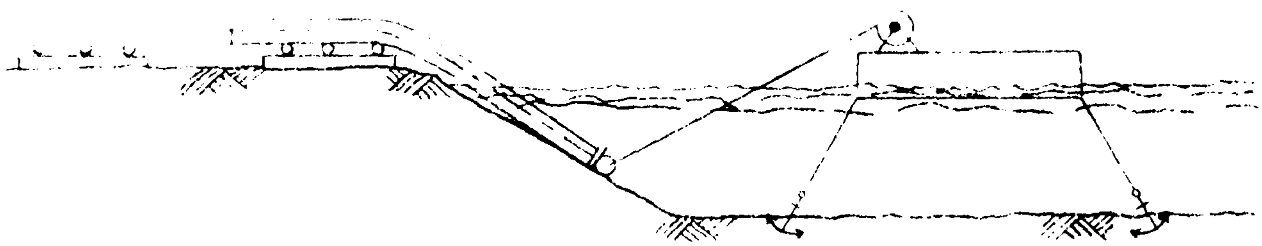

FIGURE 6-1B TYPICAL BOTTOM PULL SEQUENCE	
DRAWN BY: M. RICH	APPROVED: J.P.S.
DATE: APRIL 15, 1981	SCALE: NONE
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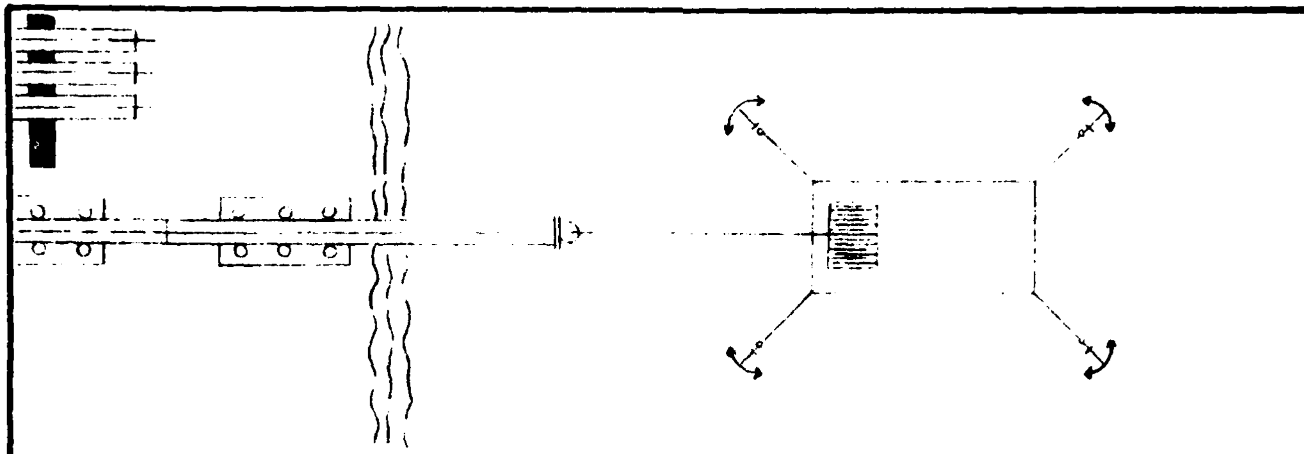
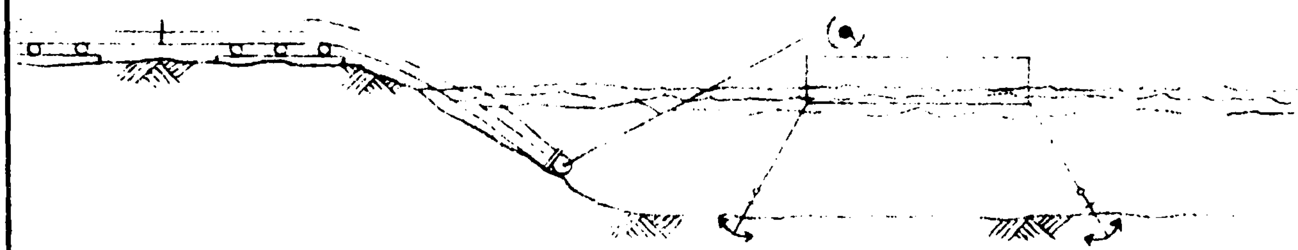


— POSITION NEXT PIPE STRING ON LAUNCHWAY.



— JOIN, INSPECT, AND FIELD COAT JOINT.

FIGURE 6-1C TYPICAL BOTTOM PULL SEQUENCE	
DRAWN BY: M. RICH	APPROVED: J.P.S.
DATE: APRIL 15, 1981	SCALE: NONE
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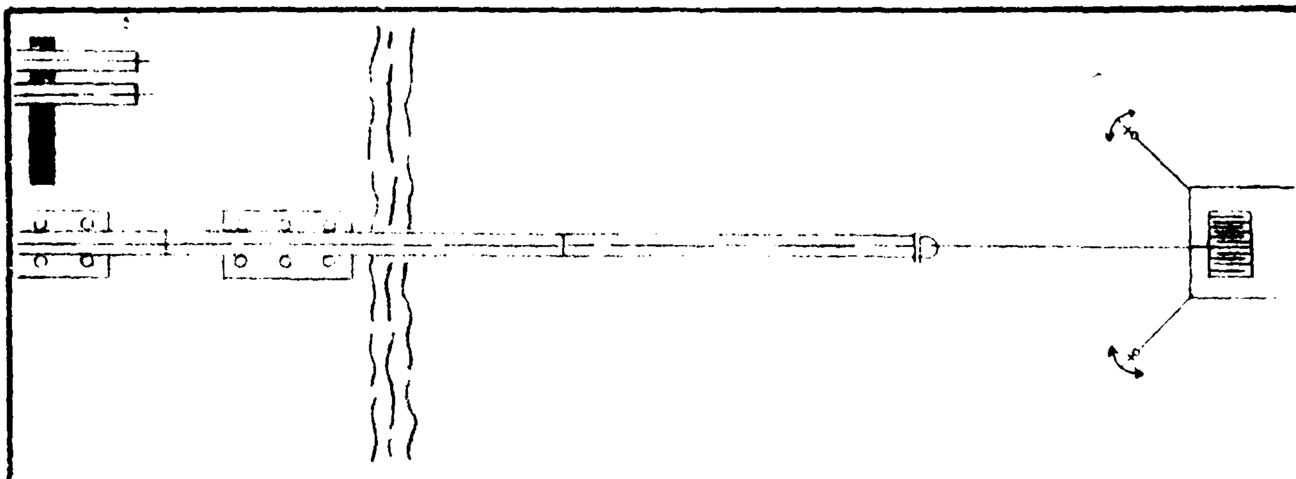

— REPEAT PULLING PROCESS.

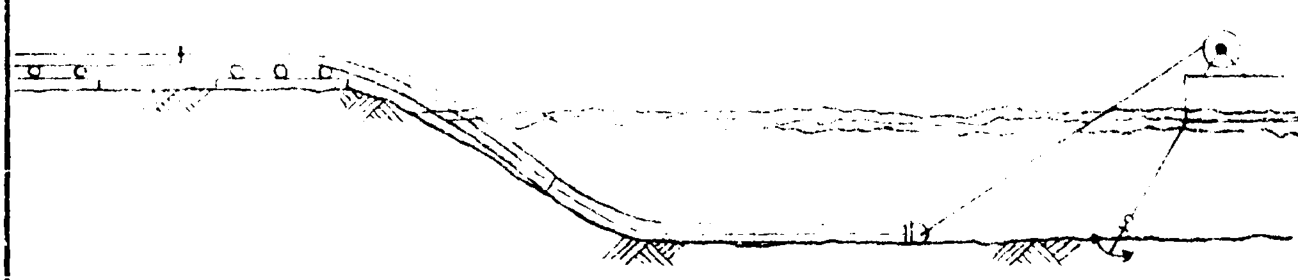

FIGURE 6-1D
TYPICAL BOTTOM
PULL SEQUENCE

DRAWN BY: M. RICH	APPROVED: J.P.[illegible]
DATE: APRIL 15, 1981	SCALE: NONE
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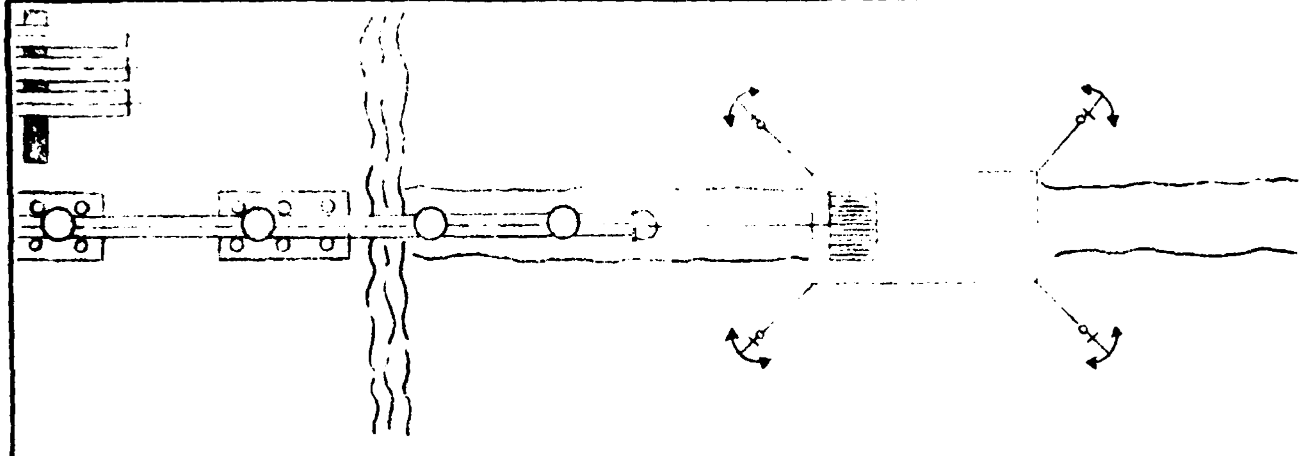
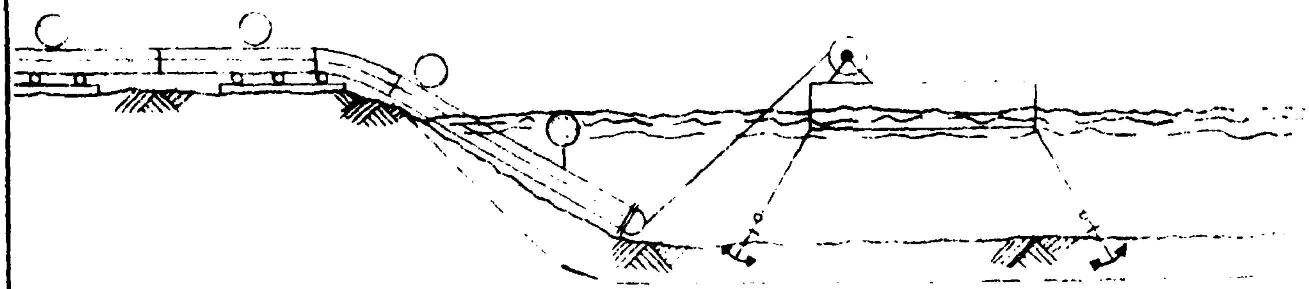
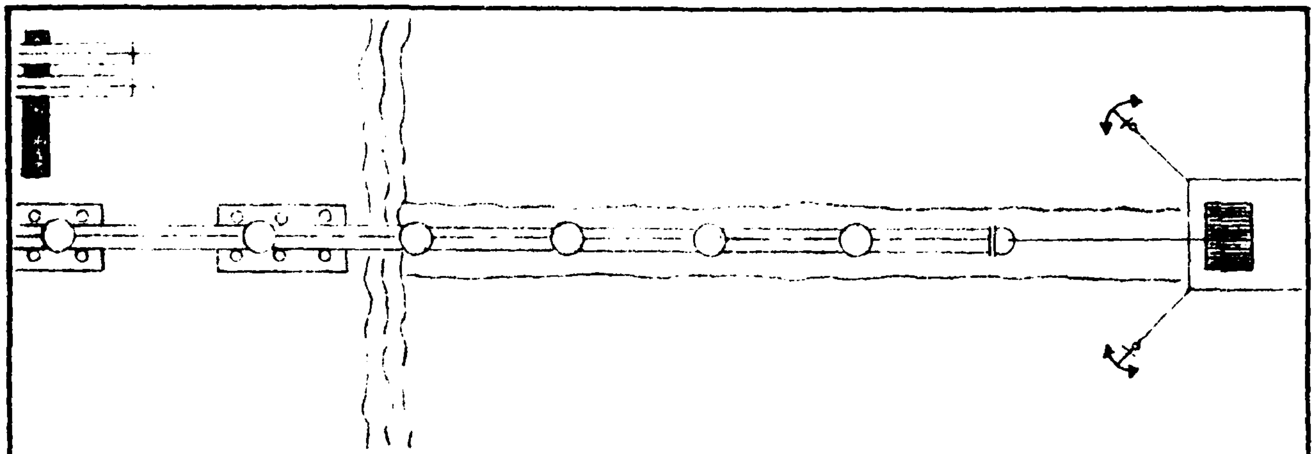


- STRING PIPE FOR JOINING .
- JOIN, INSPECT, TEST, AND FIELD COAT JOINTS
- PREPARE LAUNCHWAY AND PULL BARGE.
- PREPARE DITCH (AS APPLICABLE).



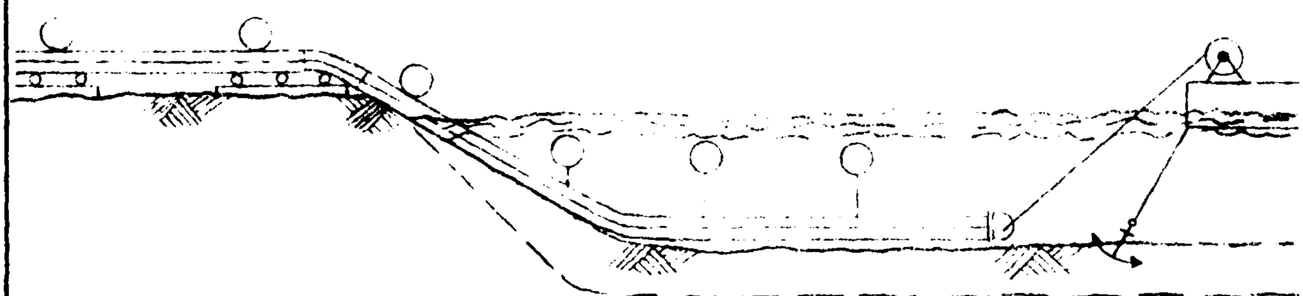
- POSITION BARGE AND ATTACH PULLING LINE TO PIPE STRING ON LAUNCHWAY.
- ATTACH FLOATATION BUOYS.
- PULL INITIAL PIPE STRING SEAWARD

FIGURE 6-2A TYPICAL OFF-BOTTOM PULL	
DRAWN BY : M. RICH	APPROVED : J.P.S.
DATE: APRIL 15, 1981	SCALE: NONE
DMJM	8413-01-01



— STOP INITIAL PULL WHEN PIPE STRING IS AT END OF LAUNCHWAY.

— POSITION NEXT PIPE STRING ON LAUNCHWAY.



— JOIN, INSPECT, AND FIELD COAT JOINT.

— ATTACH FLOATATION BUOYS TO PIPE STRING ON LAUNCHWAY.

— REPEAT PULLING PROCESS.

FIGURE 6-2B TYPICAL OFF-BOTTOM PULL	
DRAWN BY: M. RICH	APPROVED: J.P.S.
DATE:APRIL 15, 1981	SCALE: NONE
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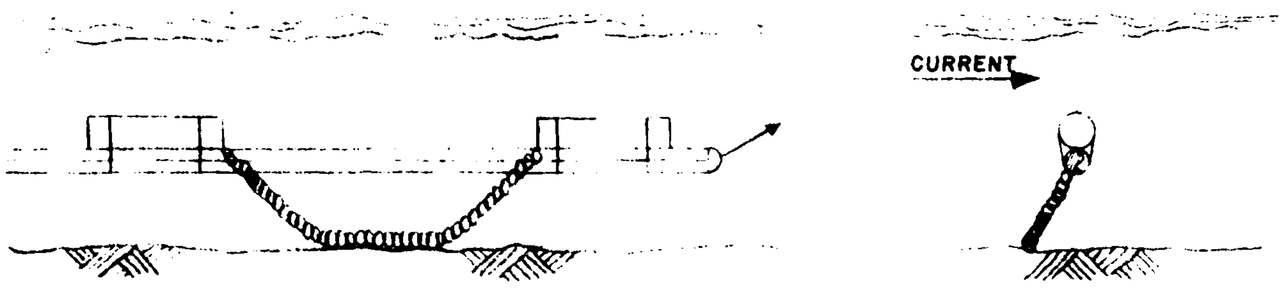
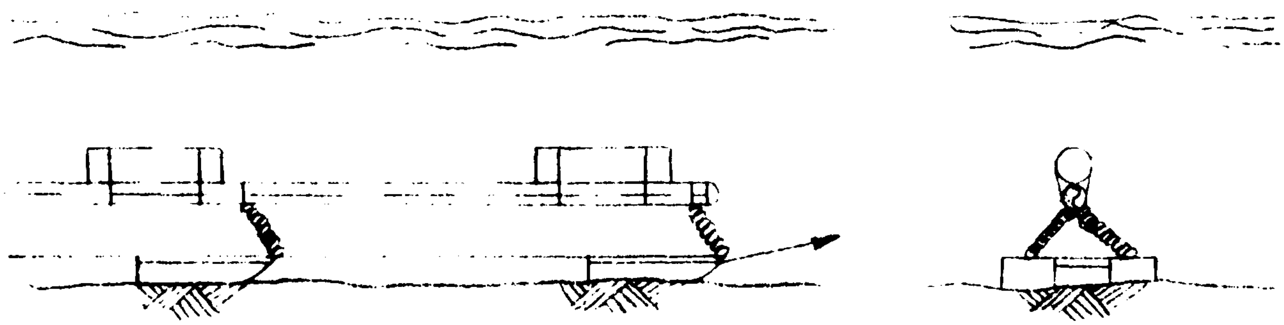


— FLOATS HOLD PIPELINE OFF BOTTOM.

— CHAINS ADD SUFFICIENT WEIGHT TO PREVENT PIPELINE FROM FLOATING TO SURFACE.

A



— OFF BOTTOM PULLING SLED CONFIGURATION.

B

FIGURE 6-3 OFF-BOTTOM PULL USING FLOAT AND CHAIN TECHNIQUE	
DRAWN BY: M. RICH	APPROVED: J.P.S.
DATE: APRIL 16, 1981	SCALE: NONE
DMJM	8413-01-01

10. Stop pull when the end of the pipe string reaches the end of the launchway; set holdback tension on pipe
11. Position next string in launchway
12. Join pipe strings
13. Inspect pipe string connection
14. Field coat pipe connection (as applicable)
15. Go to step 9. and repeat steps until pipeline is installed
16. Post-trench ditch (as applicable)
17. Test pipeline for integrity
18. Backfill pipeline (as applicable)
19. Retest pipeline for final commissioning

e) Site Restoration

f) Equipment De-Rig

g) Demobilization:
1. Personnel
2. Equipment
3. Materials

All of the major steps listed above are common to most pull projects and are self explanatory. Some of the items of concern on a typical project are:

a) Weight of pipe.
b) Seabed conditions.
c) Onshore fabrication site.
d) Pull forces required.

Weight of pipe during pulling. If an off-bottom pull or surface pull is planned, buoyancy may have to be added. If an on-bottom pull is planned it is necessary to keep the in-water weight of the pipeline as low as practical to reduce the pulling force required. Since most lines are designed to have enough weight to withstand storm waves and currents there may be too much weight for a successful pull without adding temporary buoyancy. These factors combine to make the pipeline weight control a critical factor. Most pull method projects which have failed were the result of improper weight control, generally during the continuous concrete coating operation.

Seabed conditions. Rocky bottoms can damage the coating and hinder pipe pulling. Abrupt changes in the profile or obstacles could stop the pull. Offshore preparation includes removal of obstacles discovered during the prelay survey. If some leveling or uniform sloping of the route is not done, unsupported spans of pipe will result. A maximum allowable limit must be set for these spans during design to prevent overstressing the pipe when it is filled with water or other fluids.

Onshore fabrication site. Figure 6-4 shows a typical onshore site layout and pull barge in plan view. The onshore site must be of sufficient size to join the pipe sections together to make the necessary pipe strings, position the pipe strings for launching, and launch the line. Launch site equipment includes pipe launchway rollers, pipe racks, holdback tension winch, sideboom tractors or pipe lifting devices (such as a crane), and pipe joining equipment (which is dependent upon the pipe material of construction). The launching area is generally smooth or graded to allow freedom of movement for the pipe joining and launching. Launchways are contoured to make a smooth transition to the seabed so the pipe is not over-stressed. It is sometimes necessary to fabricate trestles to provide this smooth profile for the pipeline.

Pull forces required. On actual projects the required pull forces usually exceed the theoretical values. This is particularly true of the force required to initiate movement of the pipeline. The pull sequence is usually intermittent because one pipe string is pulled along the route and then stopped while the next pipe string is being joined to it. When the joining is complete another pull is required. The force required to initiate this movement must overcome a static resistance to movement which is substantially greater than the sliding resistance after pulling has begun. Therefore, it is recommended that 50 to 100 percent spare pulling capacity be available. Holdback winches are needed to prevent the pipe strings from being pulled too far for subsequent joint connections or too fast for proper control. In areas where slopes are steep the first few pipe sections may tend to "run" down the slope without the holdback tension.

The length of the pull by this method is influenced by the capacity of the pulling equipment, the allowable tension in the pipe, the negative buoyancy of the pipe, the frictional resistance of the seabed, and the effect of current and wave forces. Pipelines up to 18 inch diameter have been on-bottom pulled over 15 miles offshore, so this method can definitely be considered state-of-the-art for this study. The method requires accurate bottom surveys and close tolerances in the application of pipe weighting. Both of these factors influence the length of the pipeline to be installed and the success of the project. Maintaining course and holding of position is helped by the pulling cables. In addition, the pull barge's positioning anchors are used to maintain the position of the barge.

Equipment requirements are relatively simple. A large winch, or chain windlass mounted on a barge serves as the offshore pull base. The barge must have sufficient anchors to counteract the pull loads. Usually a four-point mooring system is a minimum requirement and as many as eight points may be

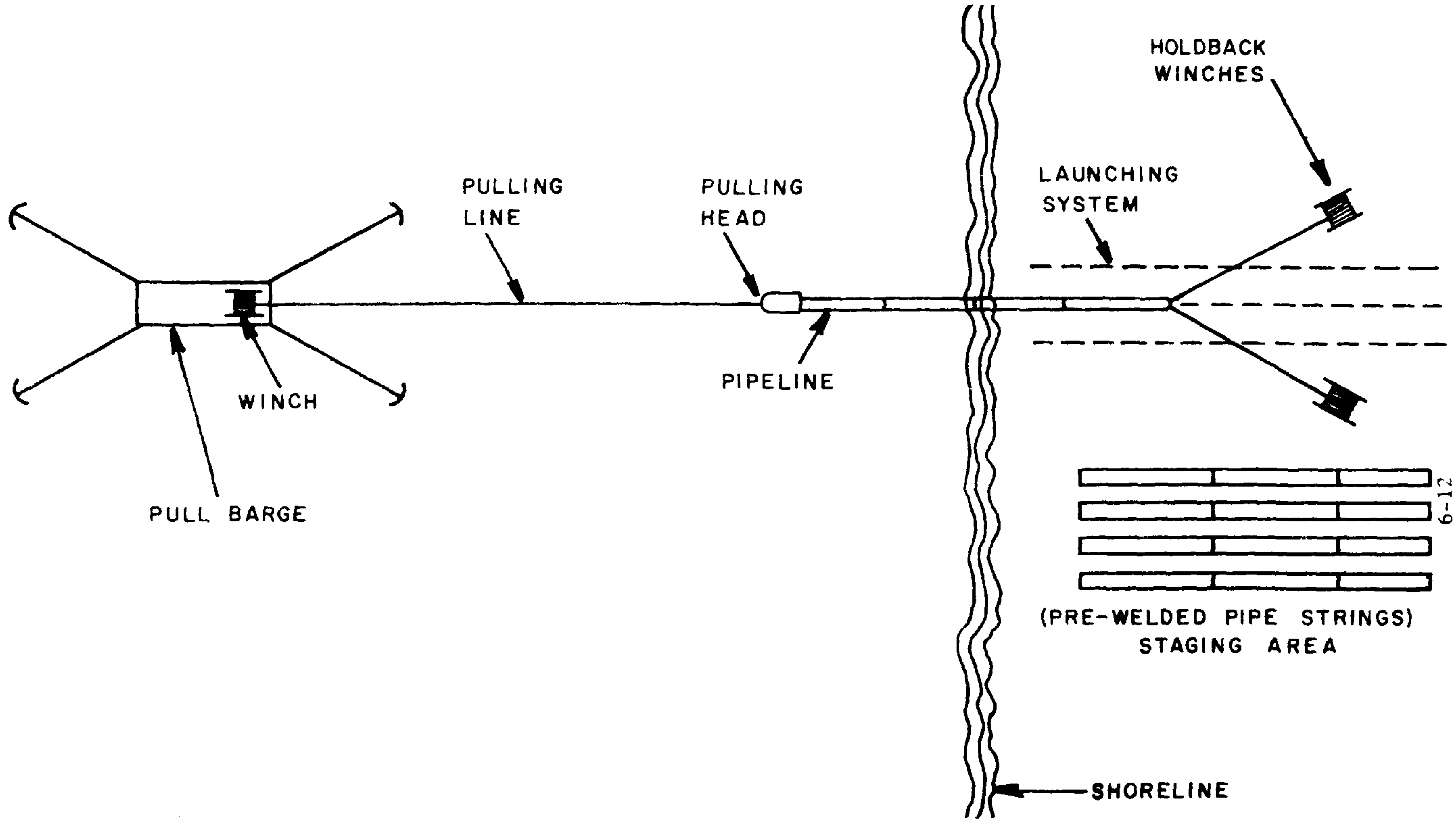


FIGURE 6-4
PULL METHOD
TYPICAL SITE LAYOUT

DRAWN BY: M. RICH	APPROVED: J.P.S.
DATE: FEB. 11, 1981	SCALE: NONE
DMJM	8413-01-01

necessary. Buoys can be fabricated on the job site if necessary. Onshore, a track and dolly system or pipe roller support units are needed to make a launchway. Onshore pipe racks can be fabricated on-site. Normally, bulldozer winches can be used for holdback purposes.

Pipe materials which are most compatible with the pull method include:

a) Steel - all sizes available, 2 to 24 inch.
b) Plastic - all sizes available, 2 to 24 inch.
c) Hose - 1 to 12 inch is available. Sizes over 6 inch diameter may require special order.
d) Flexible - 1½ to 10 inch is available and larger sizes are possible.

Advantages of the bottom pull method are:

a) The amount of overwater work, hence vunerability to adverse weather, is considerably reduced since all joining, coating, and X-ray (where applicable) is done onshore. This provides cost and schedule advantages.
b) Less marine equipment is required.
c) This is a relatively fast operation in that the pipe pull is interrupted only for moving another string onto the launching ramp, making the pipe string tie-in, and coating the joint. String length is generally governed by the available area at the launching site. These strings can be very long (possibly 5,000 feet) making interruptions infrequent. Pulling speed is generally 25 to 60 feet per minute.
d) Good control can be maintained over the pulling and holdback tensions. As a result the pipe will generally follow the predetermined course laid down by the pull line. Pylons or anchors with rollers can be installed for pulling a curve, although this is not normally necessary for short, nearshore pipelines.

When pipelines are pulled on the surface or off-bottom, the basic sequential steps are the same except that the pipe must be lowered to the seabed by releasing the floation buoys, flooding the line with water, or both. The advantages of off-bottom pulls are the reduction in pulling force requirements and the ability to manuever the line laterally. A disadvantage is that the line is subjected to wave and current forces. Some off-bottom pulls have been successful and some have been disasters. If current velocities are high, or surf conditions excessive, off-bottom pulls should be avoided. If the total length of the nearshore pipeline is over 1000 to 2000 feet, the surface pull should be avoided. Holdback tension from shore is necessary to prevent excessive bending stresses in the pipe.

Two types of buoys are used to provide the buoyancy for pull projects. They are conventional fixed volume buoys and variable volume buoys (often called "breathing buoys"). In the pipelaying operation, the buoy serves three purposes:

a) Provides floatation during the tow, or weight reduction during a bottom pull.
b) Assists in the lowering operations.
c) Used to raise the pipe string to the surface after emergency lowering.

Conventional buoys are sufficient for bottom pull projects. Breathing buoys are ordinary spherical steel buoys with vents and a rubber/nylon bladder which is pressurized with air. As the buoy descends in the sea, water enters the vents and progressively compresses the bladder thereby reducing its bouyancy.

To lower the pipeline when breathing buoys are used, the leading section is pulled to the sea bottom. As the pipe lowers in the water, the breathing buoy's bladder begins compressing and losing buoyancy. The collapse depth depends on its initial air pressure.

Once this collapse depth is reached it continues to lose buoyancy as it descends to the bottom. Before it reaches bottom, it must lose enough buoyancy so that the weight of the lower portion of the submerged pipe string becomes great enough to pull the next buoy down to a depth where its bladder begins collapsing, thereby setting off a chain reaction so that the pipe string will sink of its own accord.

The success of this method depends on a predetermined design requiring a proper balance between five variables. These are:

a) Submerged weight of the pipeline.
b) Holdback tension.
c) Spacing and sizing of the breathing buoys.
d) Initial pressure in the bladder.
e) Depth of water.

Past experience indicates that the accurate prediction of these variables is difficult and several will vary during the installation. A complicated mathematical analysis is necessary both before and during assembly. There is also the problem of controlling the holdback tensions, buoy spacings, and concrete coating uniformity. Few firms use this complicated procedure today.

Advantages of the off-bottom pull and surface pull methods are:

a) Can be used with steel, plastic, and flexible pipe material.

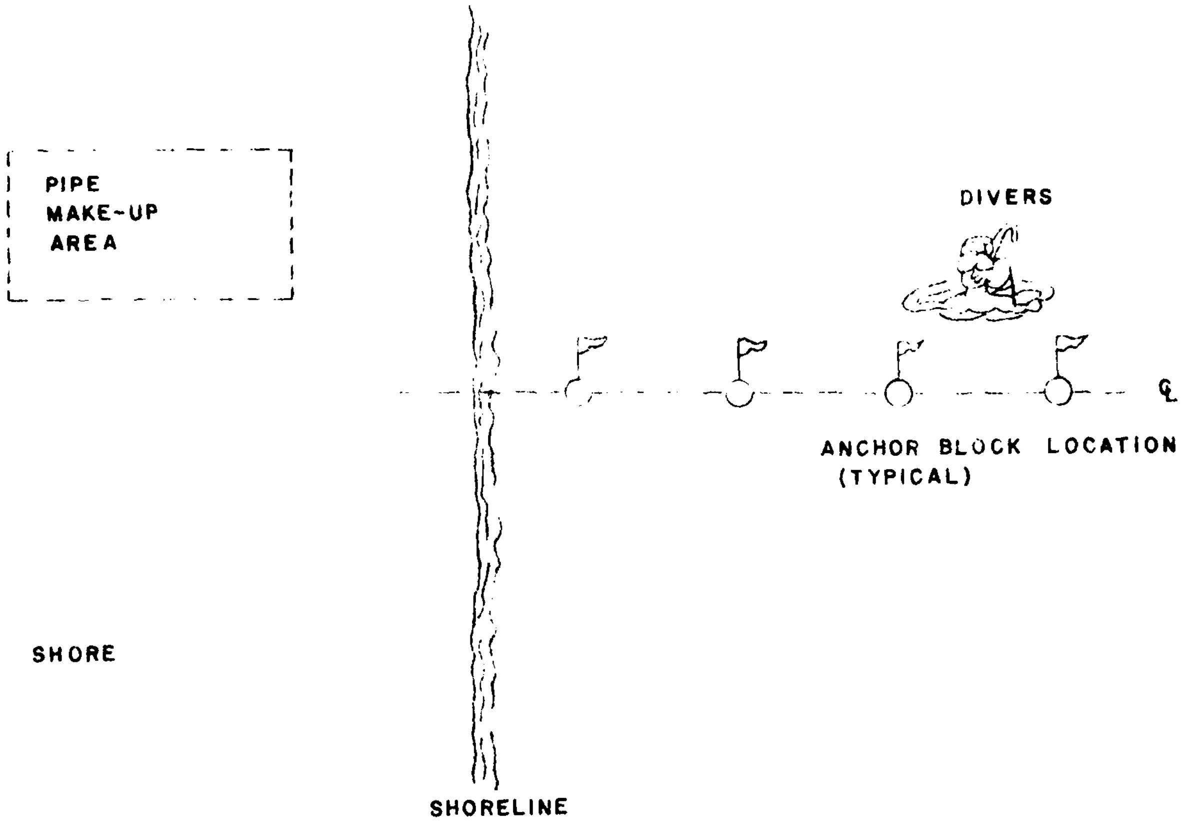
b) Pipe coatings are not damaged during pulling.
c) All fabrication of pipe joints is done onshore.

Disadvantages of the off-bottom pull and surface pull methods are:

a) Total lengths which can be pulled are limited with moderate sea currents.
b) Attachment and release of buoys is exacting and often difficult.
c) Requires very calm offshore conditions.

A variation of the pull method is the "Cable Stabilized Off-Bottom Pull". The pipeline is installed by stretching a cable along the route for alignment and stability, and pulling a floating or buoyed line into place along the cable. This method was used successfully by the Air Force for small (6 inch and 8 inch) fuel unloading lines at Eniwetok and Okinawa. Plastic pipes with cast-on floats were used for most of the offshore portion. After installation the cable served as the stability system. Concrete anchors were used to hold the cable in place. Pendant lines at 50 foot intervals were used to affix the floating pipeline to the cable. These tethered pipelines float a few feet off-bottom and swing from side to side with the tides and currents. After about five years of service and several severe storms, the lines were reportedly in satisfactory condition. This method is limited to small diameter pipelines since larger, more rigid lines could not withstand the large swings with current changes. An advantage of this method is its adaptability to the use of plastic pipe. It is a very resource efficient concept. Local labor once trained can be used to connect plastic pipe sections together. Because plastic is light weight, the sections can be handled and launched manually. Figures 6-5A thru 6-5E shows the sequential steps of this method variation.

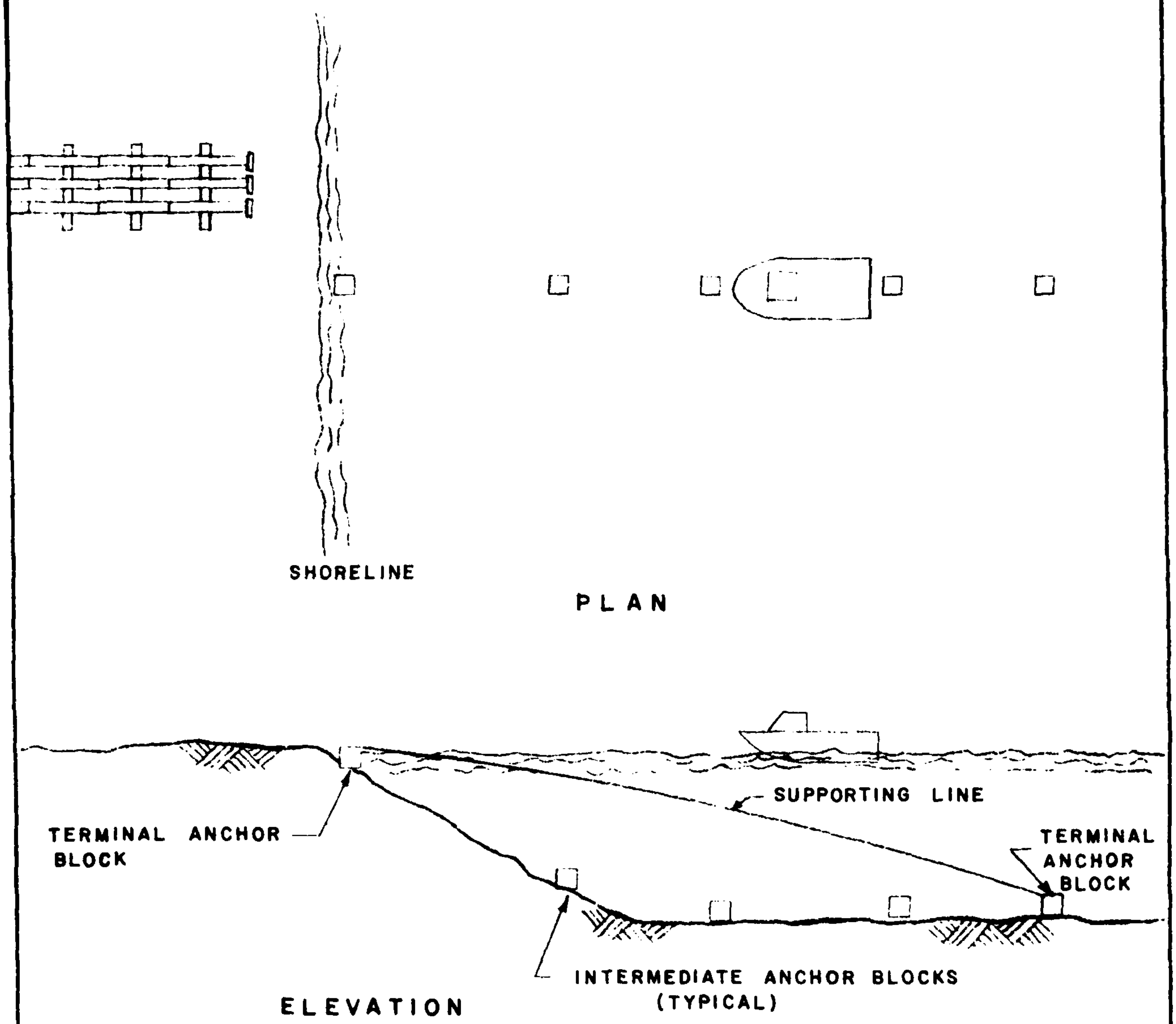
Another interesting variation which is pertinent to this study is discussed in Pipeline Installation References No. 21. Sun Oil Company used a modified bottom pull to install three parallel (one 6 inch and two 8 inch diameter) pipelines between two offshore platforms off the California coast. Spherical mine net buoys (World War II surplus) were used to form wheel and axle type supports for the pipe string. Pipe strings were fabricated onshore complete with the spherical wheel support units and pulled into place offshore with tugboats. The spherical wheels rolled along the firm bottom and prevented damage to the pipeline coating. When the pipeline was properly positioned, the wheel assemblies were released. Figure 6-6 shows the pipe pull configuration. Since the possibility exists that surplus mine net bouys are available to the UCT/NMCB, this concept should be considered for further study.



INSTALLATION PREPARATION:

- CONDUCT SEABED PROFILE SURVEY AND INSPECT FOR OBSTACLES.
- ESTABLISH SURVEY BASELINE AND CONTROL POINTS.
- LAYOUT ANCHOR BLOCK LOCATIONS, PIPELINE ROUTE, AND WORK AREAS.
- MOBILIZE MATERIALS, EQUIPMENT, AND PERSONNEL.

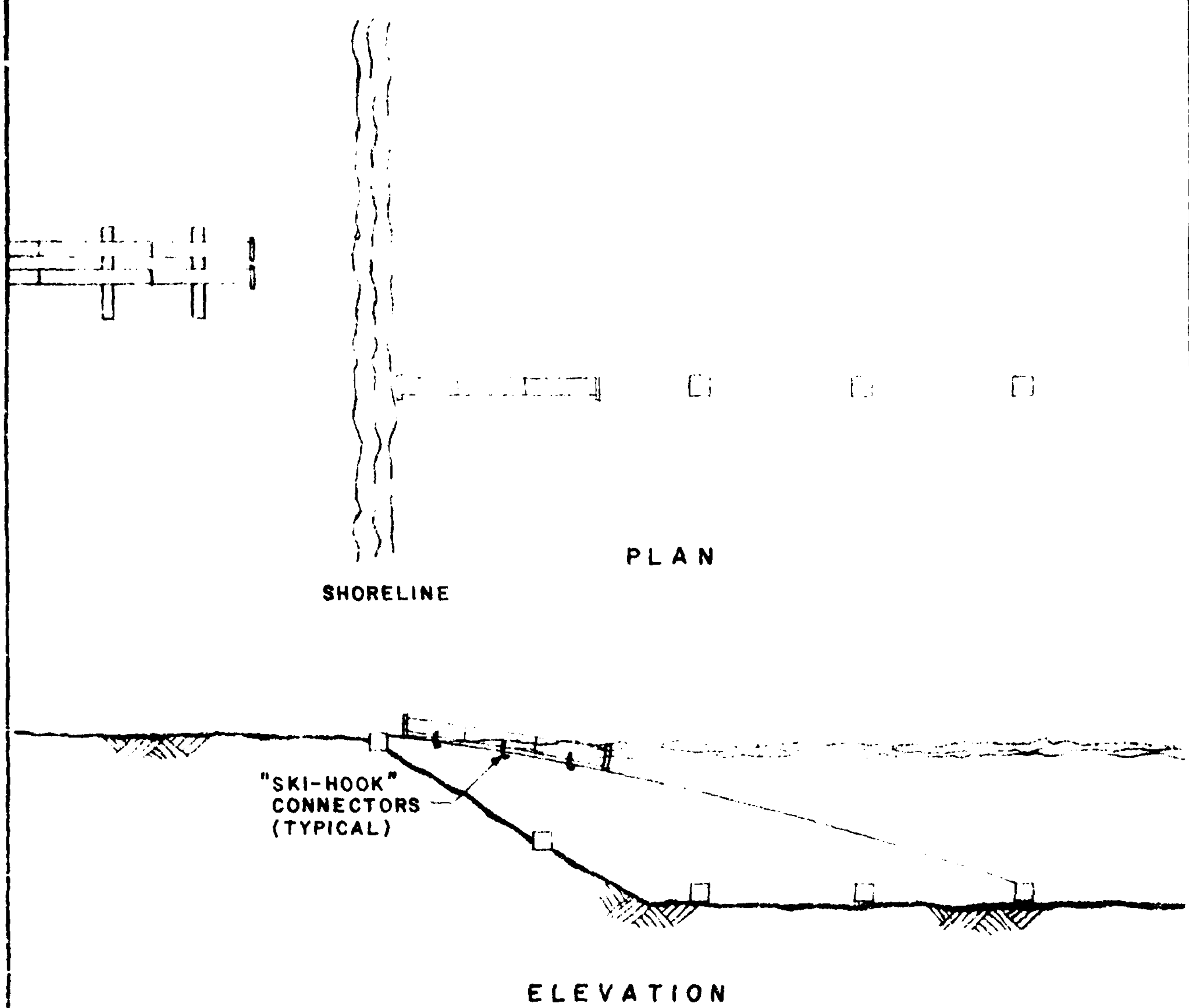
FIGURE 6-5A CABLE STABILIZED OFF-BOTTOM PULL	
DRAWN BY: M. RICH	APPROVED: B.W.M.
DATE: APRIL 27, 1981	SCALE: NONE
DMJM	8413-01-01



INSTALLATION:

- FABRICATE PIPE JOINTS INTO PIPE STRINGS WITH FLANGED END CONNECTIONS AND SKI-HOOK SUPPORTING LINE CONNECTORS.
- SET TERMINAL AND INTERMEDIATE ANCHOR BLOCKS WITH LARC OR LCU.
- ATTACH SUPPORTING LINE TO TERMINAL ANCHOR BLOCKS.

FIGURE 6-5B CABLE STABILIZED OFF-BOTTOM PULL	
DRAWN BY: M. RICH	APPROVED: B.W.M.
DATE: APRIL 27, 1981	SCALE: NONE
DMJM	8413-01-01



INSTALLATION:

— ENGAGE "SKI-HOOK" CONNECTORS TO SUPPORTING LINE LEADING THE FRP PIPE INTO THE WATER.

FIGURE 6-5C CABLE STABILIZED OFF-BOTTOM PULL	
DRAWN BY: M. RICH	APPROVED: B.W.M.
DATE: APRIL 27, 1981	SCALE: NONE
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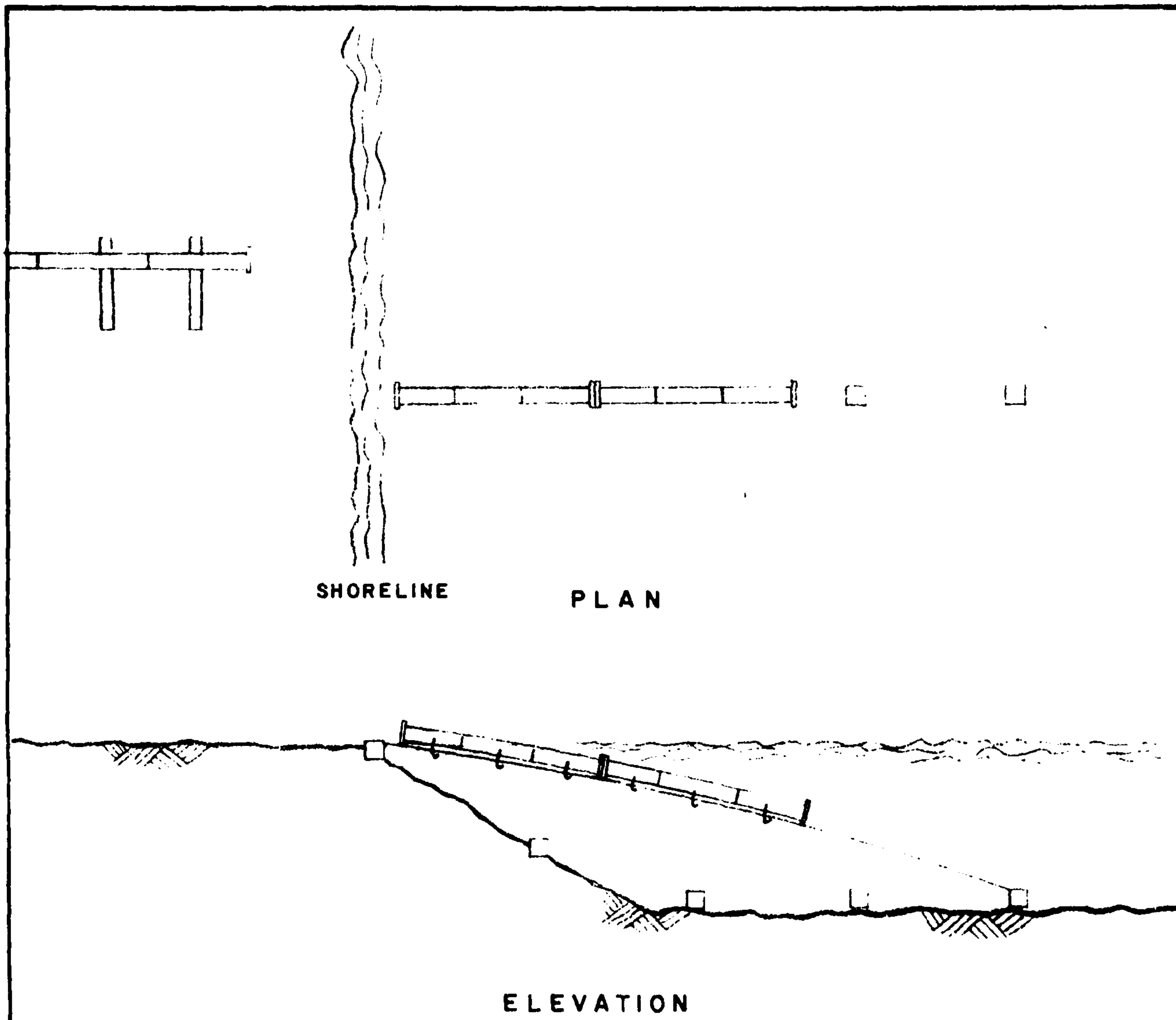
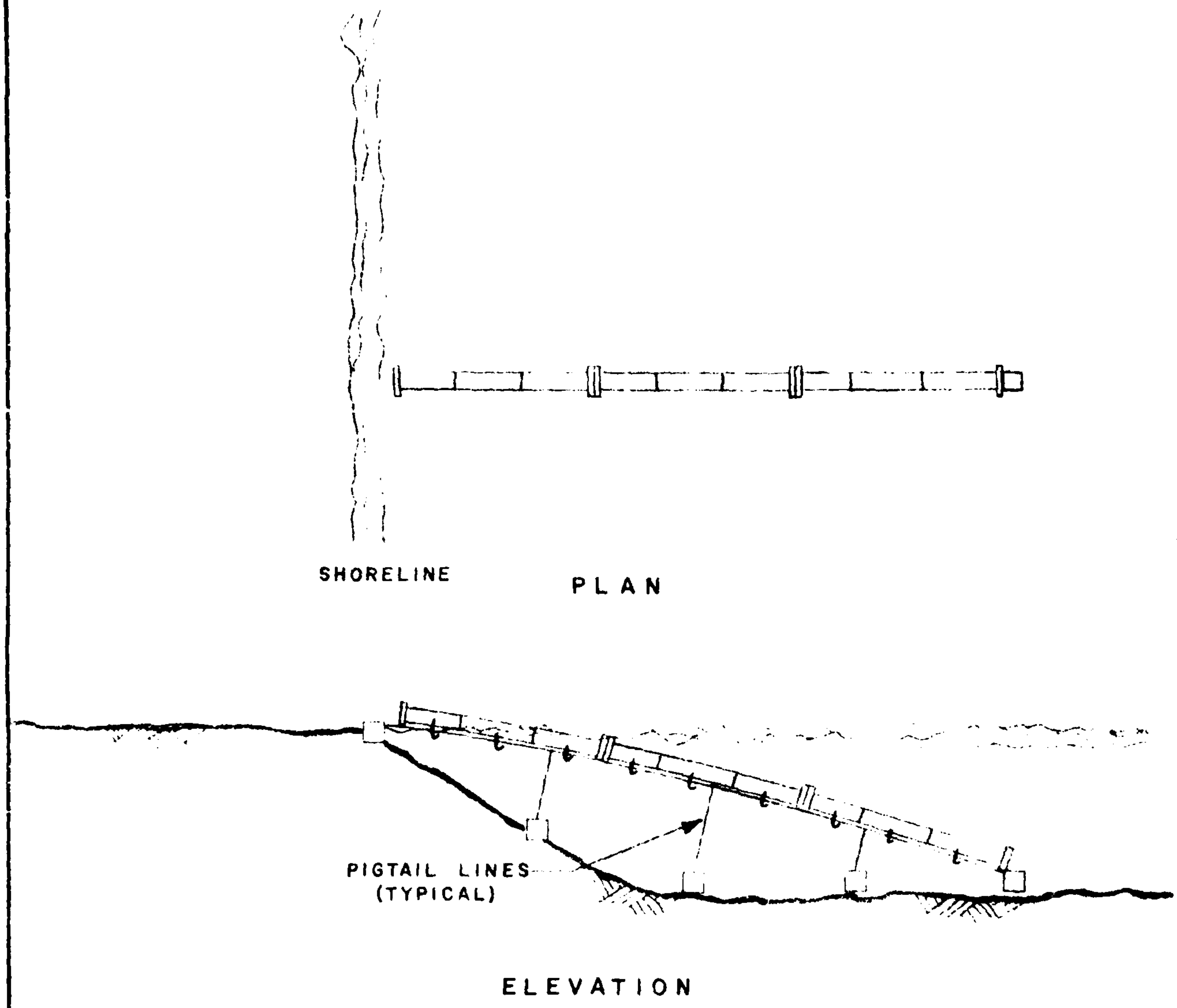


INSTALLATION:

- CONNECT NEXT PIPE STRING TO PREVIOUSLY LAID PIPE STRING.
- ENGAGE SKI-HOOK CONNECTORS TO SUPPORTING LINE LEADING NEXT STRING INTO WATER.

FIGURE 6-5D
CABLE STABILIZED
OFF-BOTTOM PULL

DRAWN BY: M. RICH	APPROVED: B.W.M.
DATE: APRIL 26, 1981	SCALE: NONE
DMJM	8413-01-01



COMPLETION:

— CONTINUE LAYING FRP PIPE STRINGS UNTIL COMPLETE.

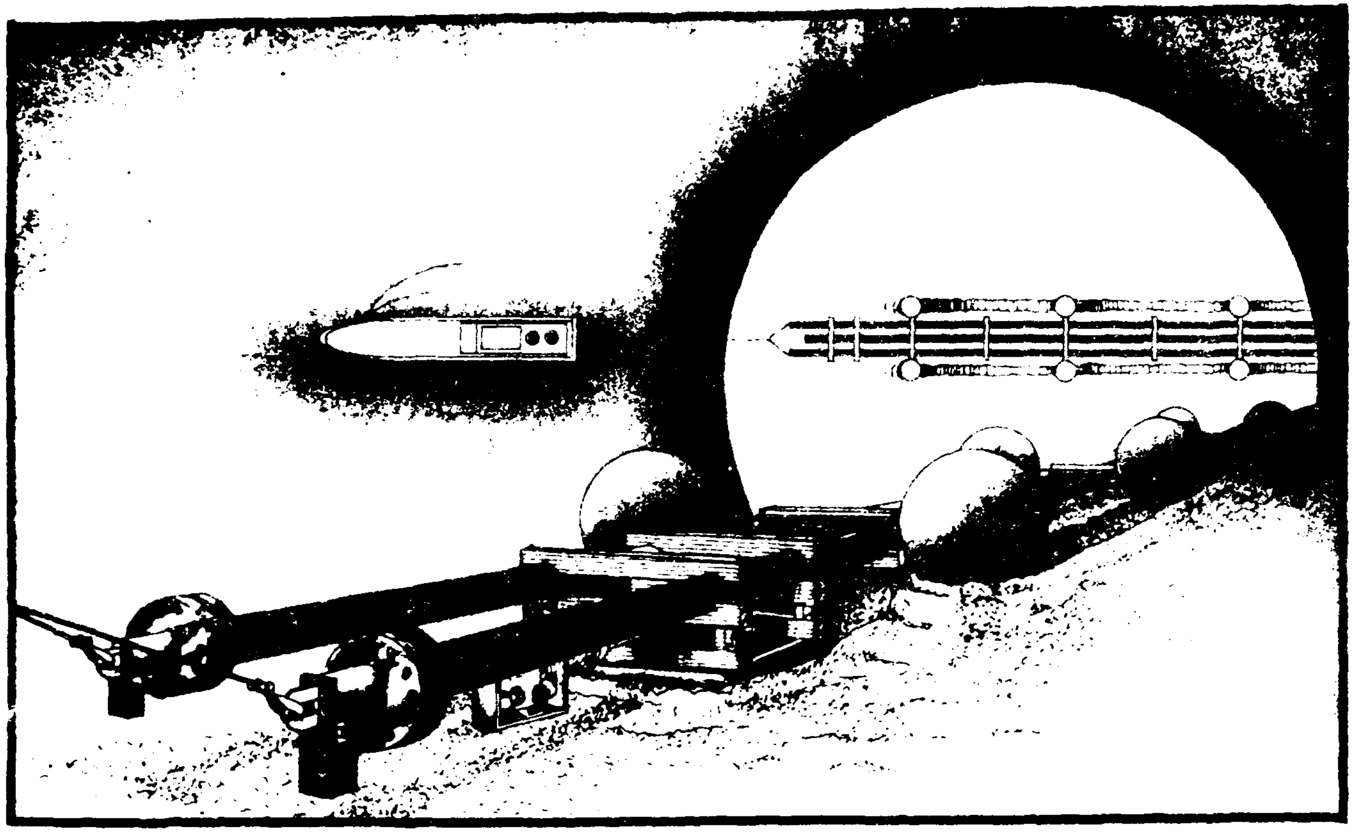
— ATTACH PIGTAIL LINES TO INTERMEDIATE ANCHOR BLOCKS AND SUPPORTING LINE. PIPELINE IS STABILIZED AND RESTRAINED FROM EXCESSIVE MOVEMENT.

— RESTORE SITE.

— DEMOBILIZE EQUIPMENT AND PERSONNEL.

FIGURE 6-5E
CABLE STABILIZED
OFF-BOTTOM PULL

DRAWN BY: M. RICH	APPROVED: B.W.M.
DATE: APRIL 26, 1981	SCALE: NONE
DMJM	8413-01-01



* FROM: "FLOW LINE GETS WHEELS FOR OCEAN FLOOR TOW", <u>PETROLEUM ENGINEER INTERNATIONAL</u>, FEBRUARY 1981, NO 2, VOL. 53, P. 26.

FIGURE 6-6 MODIFIED PULL METHOD CONFIGURATION *	
DRAWN BY J. DENTON	APPROVED J.P.S.
DATE FEB. 9, 198	SCALE NONE
DMJM	8413-01-01

6.1.2 Reel Method

For the Reel Method, pipe is joined into long lengths onshore and then spooled onto a reel. When steel pipe is used, it is stressed beyond yield to reduce the pipe's bending radius to practical dimensions. Flexible pipe and hose have also been installed from a reel. Reels can be permanently mounted on a barge, or portable units for a temporary mounting may be utilized.

In the laying operation, the pipe is unspooled from the reel, passed through straightening rollers (if steel), then over the launchway which confines or restrains it to a predetermined radius of curvature. The barge is towed along the pipeline route unspooling pipe as it advances. A tensioning device on the reel keeps the pipe in tension during laying to prevent overstress or buckling. Figure 6-7 illustrates a typical reel barge.

One tugboat is used to tow the reel barge. A second tug may be used alongside the reel barge to keep it in line, if necessary.

Sequential steps of the Reel Method include:

a) Mobilization:
   1. Personnel
   2. Equipment
   3. Materials
b) Equipment Rig-Up
c) Site Preparation:
   1. Onshore
   2. Offshore
d) Construction:
   1. Join pipe to form continuous string
   2. Inspect pipe joints (including hydrostatic test)
   3. Field coat pipe joint (as applicable)
   4. Spool pipe string onto large diameter reel
   5. Mobilize reel (or barge-mounted reel) to site
   6. Mount reel on barge (unless barge-mounted reel unit is used)
   7. Position barge-mounted reel
   8. Secure or otherwise anchor leading end of continuous pipe string
   9. Transport reel barge along right-of-way, unspooling pipe
   10. Continue until all pipe is unspooled from the reel
   11. Join spooled pipe from another reel:
       a. Remove empty spool
       b. Replace with a spool loaded with pipe
       c. Join pipe, inspect, field coat (as applicable)
       d. Continue laying operations

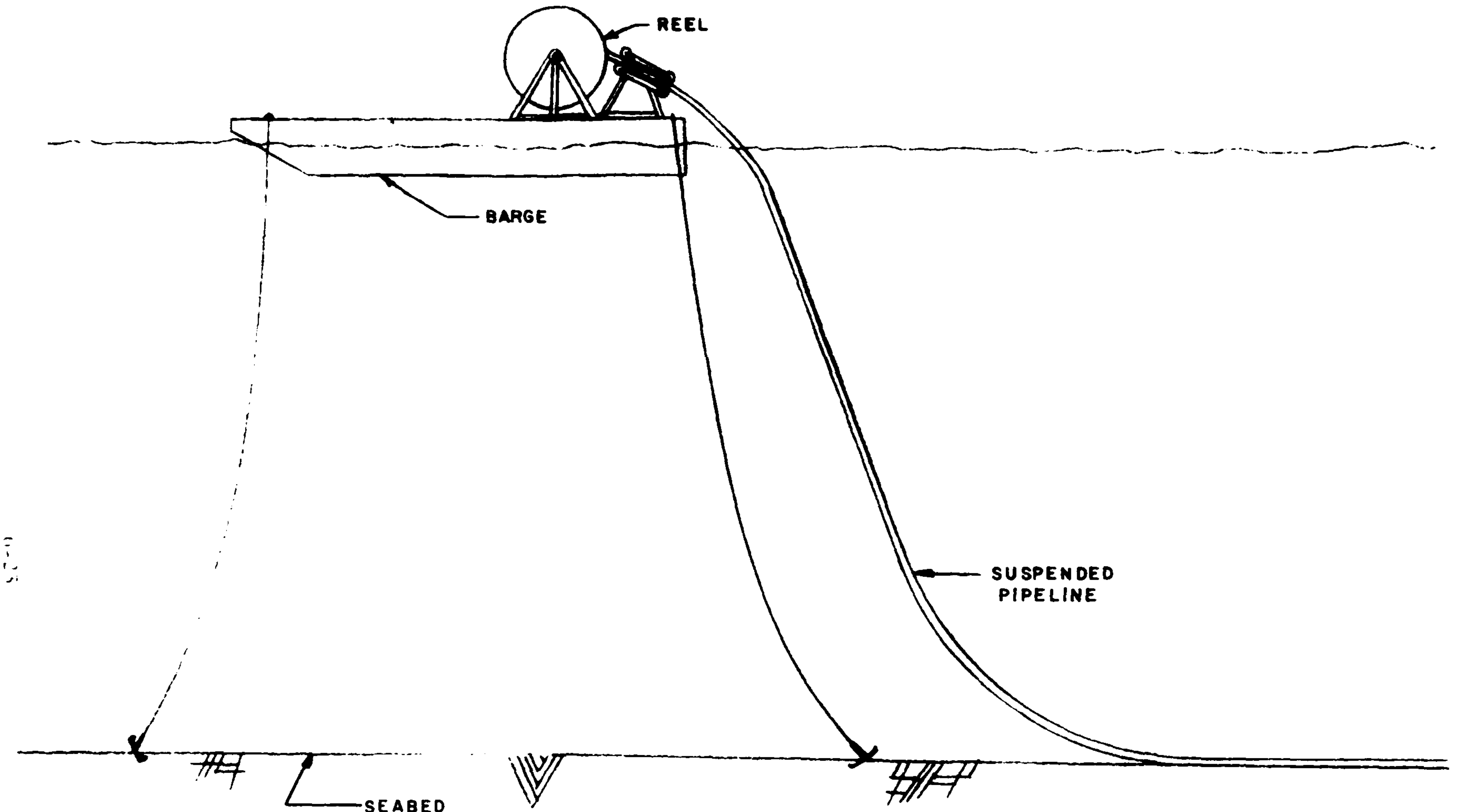


FIGURE 6-7
REEL BARGE
PIPE CONFIGURATION

DRAWN BY: J. DENTON	APPROVED: J. P. S.
DATE: FEB. 10, 1981	SCALE: NONE
DMJM	8413-01-01

12. (Alternative to Step 11)
    a. Cap end of pipe
    b. Lower pipe to seabed
    c. Mobilize reel barge to pipe facility and spool another continuous pipe string onto the reel
    d. Return to site and raise pipe from the seabed
    e. Join pipe, inspect, field coat (as applicable)
    f. Continue laying operations
13. Continue until pipeline is installed
14. Post-trench ditch (as applicable)
15. Backfill pipeline (as applicable)
16. Test pipeline for integrity

e) Site Restoration
f) Equipment De-Rig
g) Demobilization:
    1. Personnel
    2. Equipment
    3. Materials

There are several variations of the reel method concept. Both a vertical and a horizontal reel barge are currently in use. These are barges with the reel permanently mounted on the barge deck. Both are designed for steel pipe with diameters up to 16 inches. Portable pipe reels have been designed for both steel pipe and flexible pipe, generally in the 6 inch and under pipe diameter range.

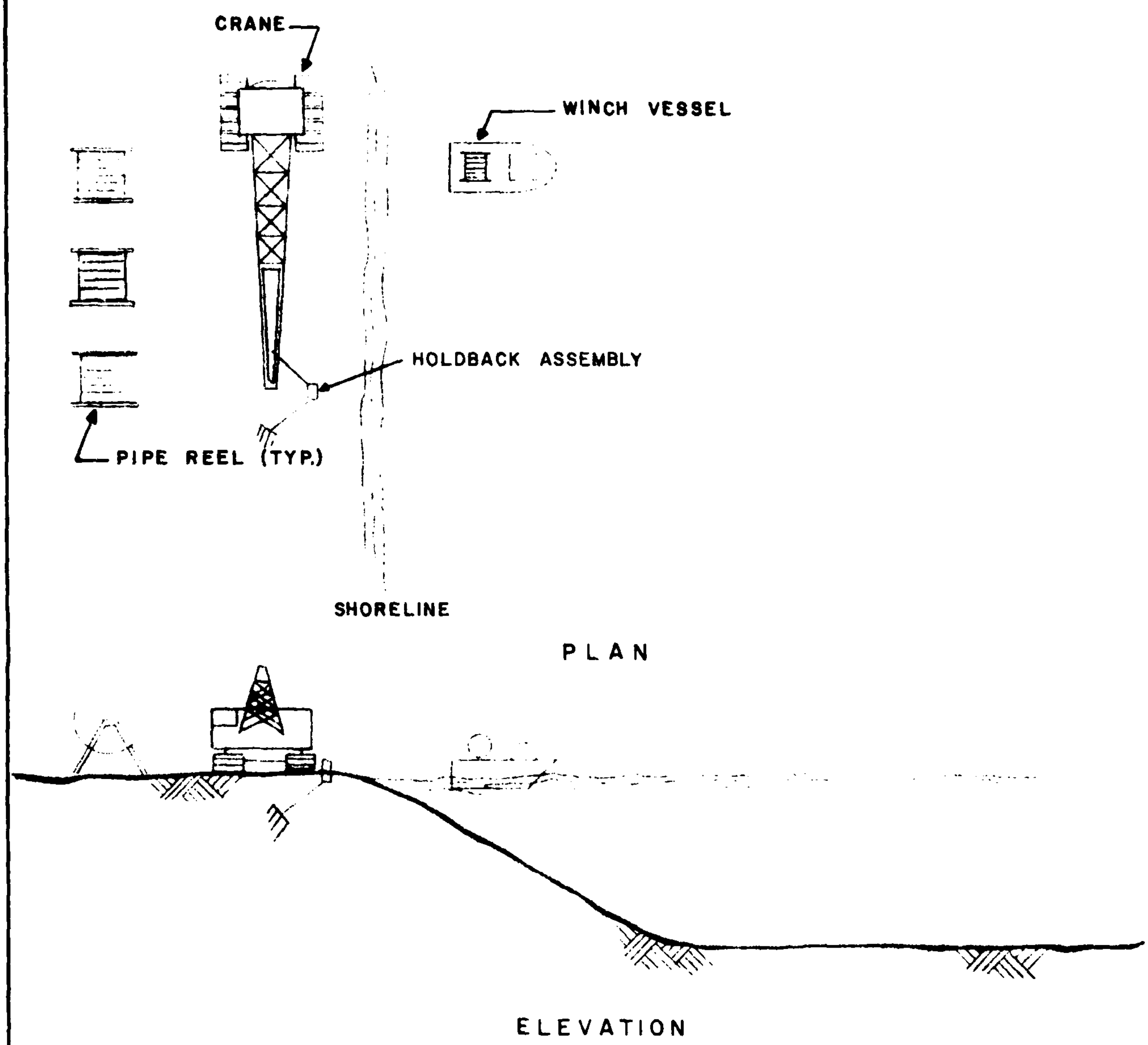
Another variation of the reel method is to position the reel of pipe onshore and unspool it along the pipeline route with a tugboat on similar vessel. Figures 6-8A thru 6-8G show sequential steps for the pipeline installation.

Reel systems for steel pipe consist of:

a) The reel.
b) A tensioning system (generally built into the axle of the reel).
c) Straightening roller system to remove the permanent set (bending) of steel pipe induced during the spooling-up operation.
d) Launchway to guide the pipe to smooth exit from the barge. These can be either short or long and simple or complex depending on design constraints.

Auxiliary equipment required is:

a) A floating vessel to support the reel.
b) Tug for towing or other propulsion for the vessel.
c) Other floating craft required for routine logistic support (such as a crewboat).



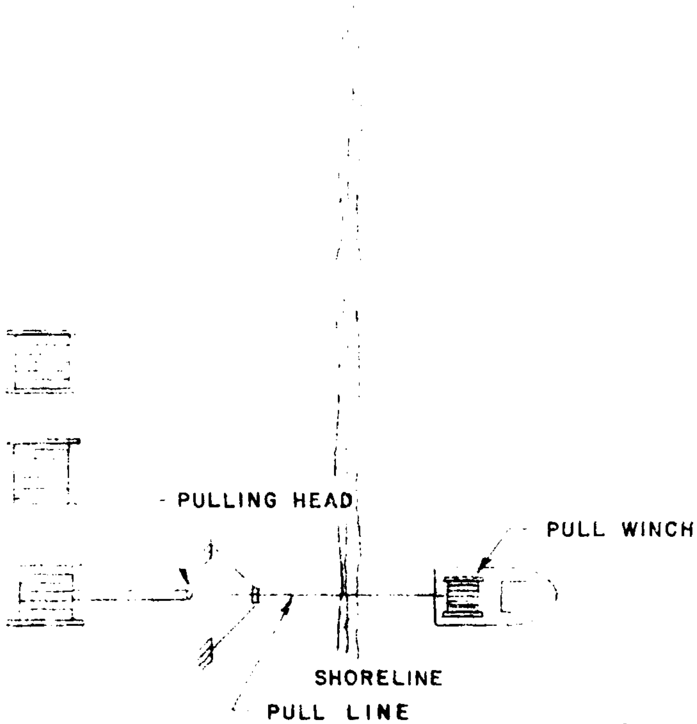
INSTALLATION PREPARATION :

- CONDUCT SEABED PROFILE SURVEY AND INSPECT FOR OBSTACLES.
- ESTABLISH SURVEY BASELINE AND CONTROL POINTS.
- LAYOUT PIPELINE ROUTE AND WORK AREAS.
- MOBILIZE MATERIALS, EQUIPMENT, AND PERSONNEL.

FIGURE 6-8A

TYPICAL ONSHORE REEL

DRAWN BY: M. RICH	APPROVED: B.W.M.
DATE: APRIL 27, 1981	SCALE: NONE
DMJM	8413-01-01



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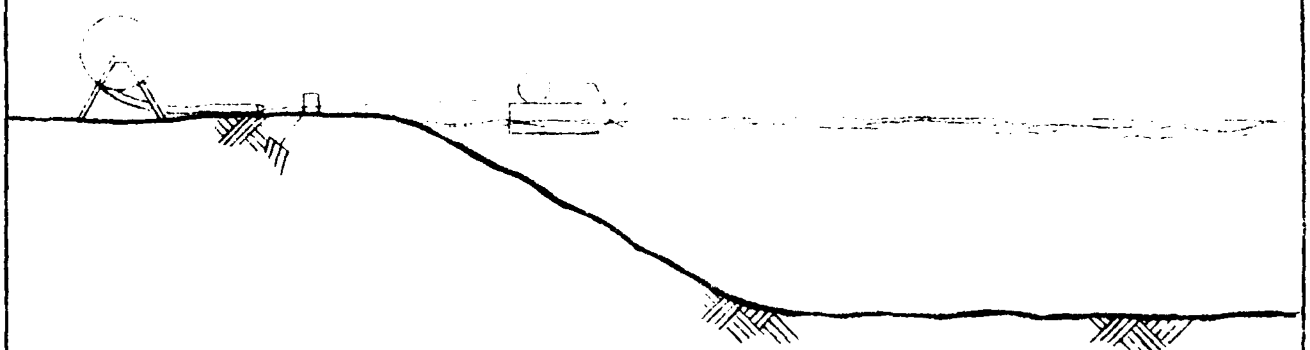

ELEVATION

PULLING PREPARATION :

— LOCATE PIPE REELS AND HOLDBACK ASSEMBLY.

— ATTACH PULLING HEAD TO PIPE. ATTACH PULLING LINE.

FIGURE 6-8B TYPICAL ONSHORE REEL	
DRAWN BY: M. RICH	APPROVED: B.W.M.
DATE: APRIL 27, 1981	SCALE: NONE
DMJM	8413-01-01

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NEARSHORE PIPELINE INSTALLATION METHODS.(U)
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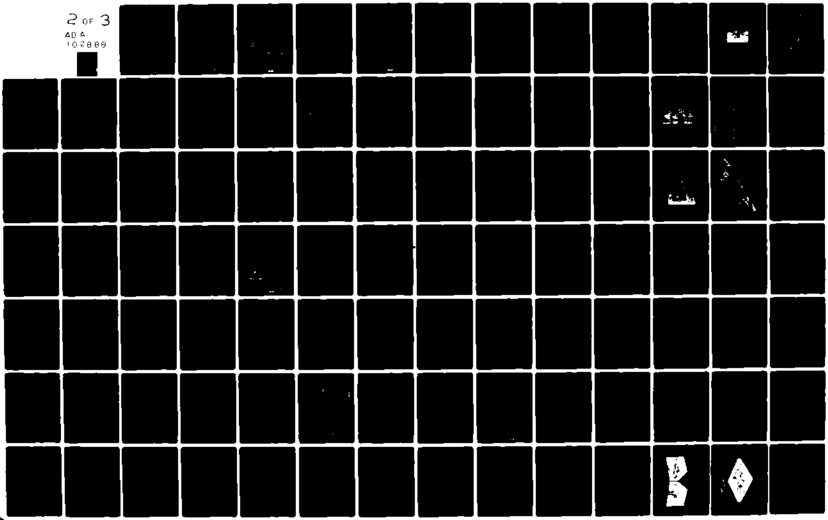
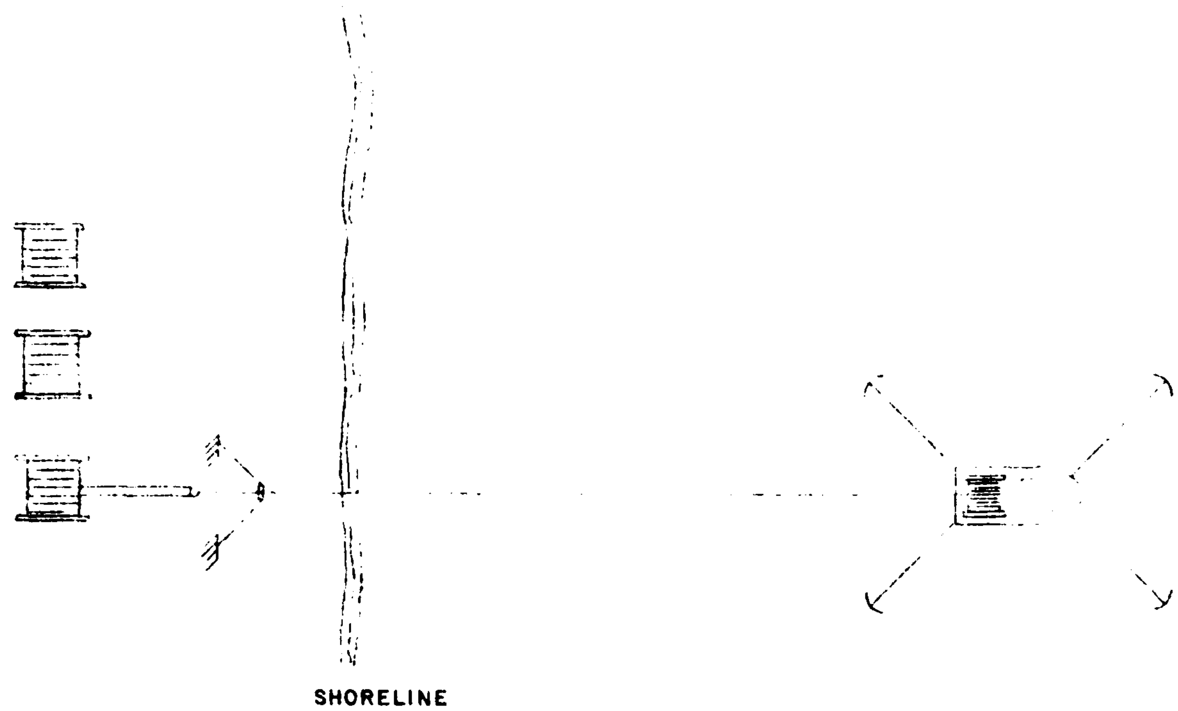
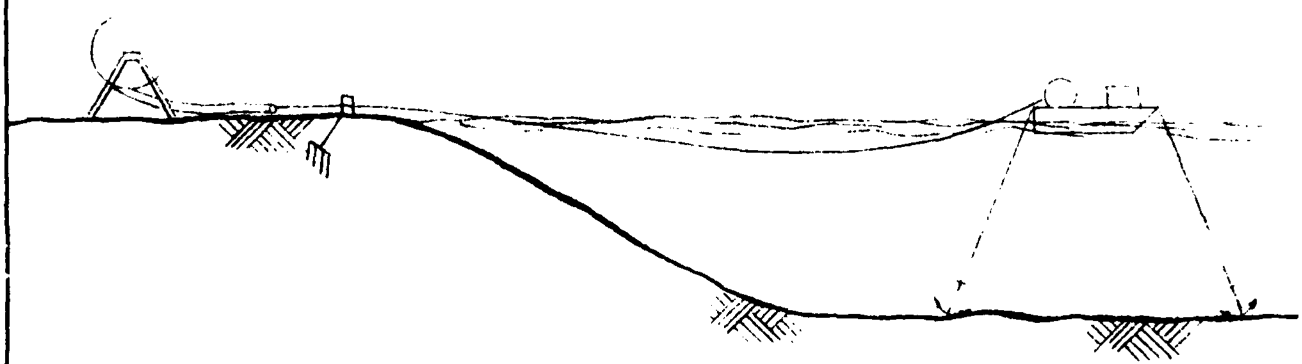


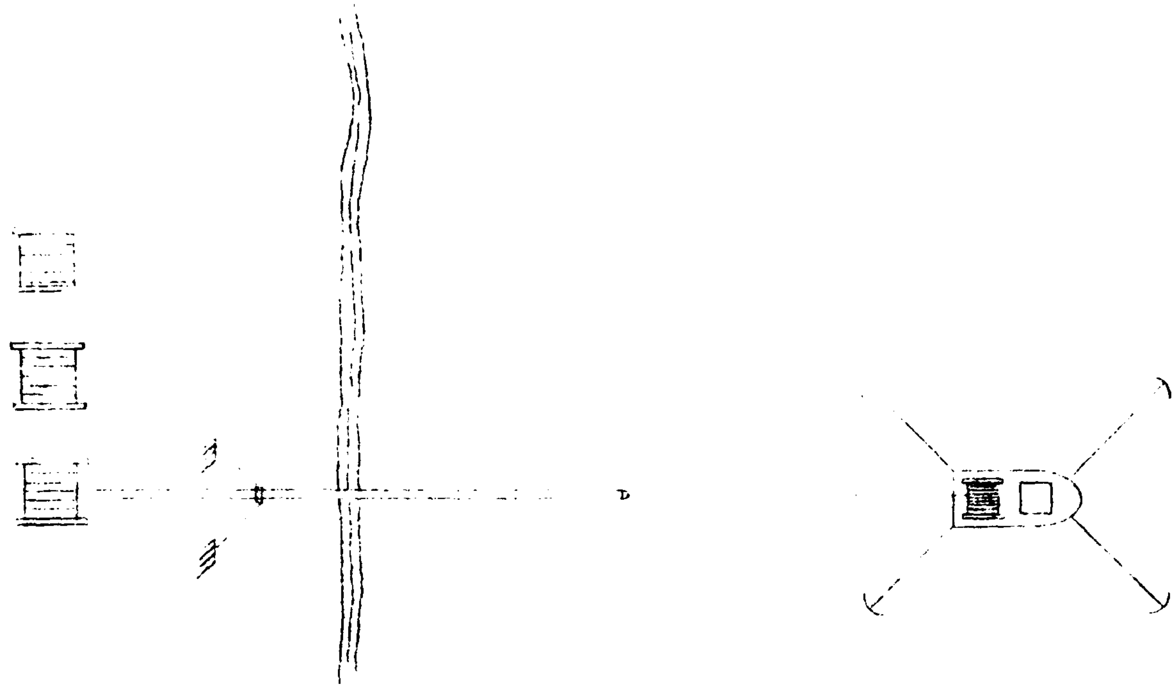




PULLING PREPARATION:

— POSITION WINCH VESSEL FOR PULLING OPERATIONS. SET ANCHORS.

FIGURE 6-8C TYPICAL ONSHORE REEL	
DRAWN BY: M. RICH	APPROVED: B.W.M.
DATE: APRIL 27, 1981	SCALE: NONE
DMJM	8413-01-01



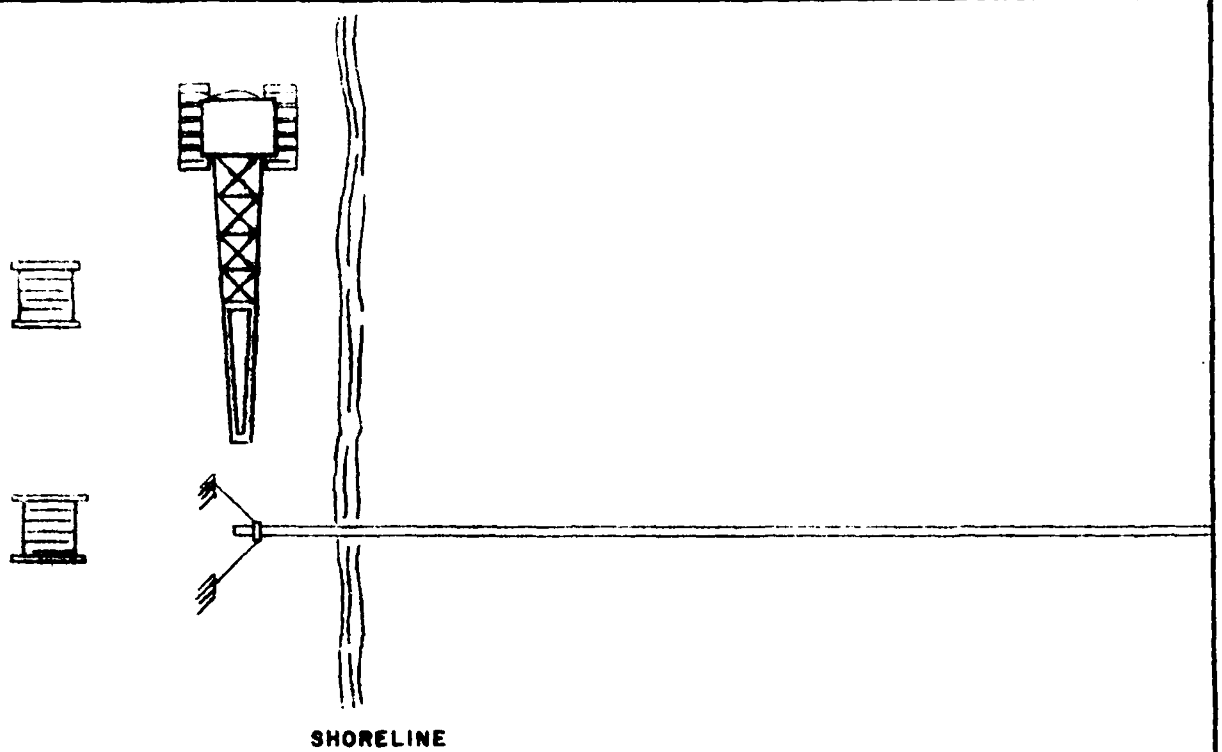
PLAN

ELEVATION

PULLING:

— PULL PIPE FROM REEL WITH WINCH VESSEL. SET HOLDBACK TENSION AND REPOSITION PULL VESSEL. RELEASE HOLDBACK AND PULL PIPE. REPEAT UNTIL PIPE SPOOL IS EMPTY.

FIGURE 6-8D TYPICAL ONSHORE REEL	
DRAWN BY: M. RICH	APPROVED: B.W.M.
DATE: APRIL 27, 1981	SCALE: NONE
DMJM	8413-01-01



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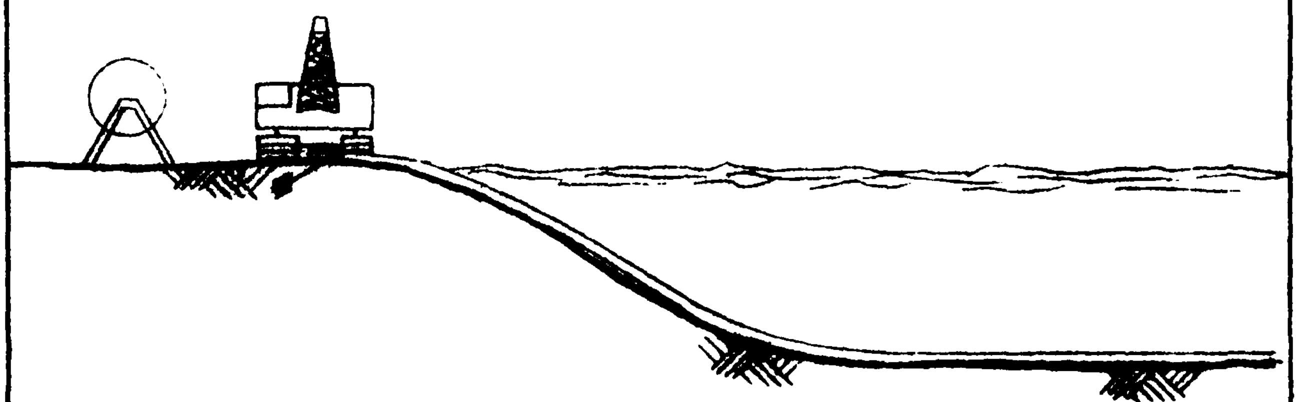


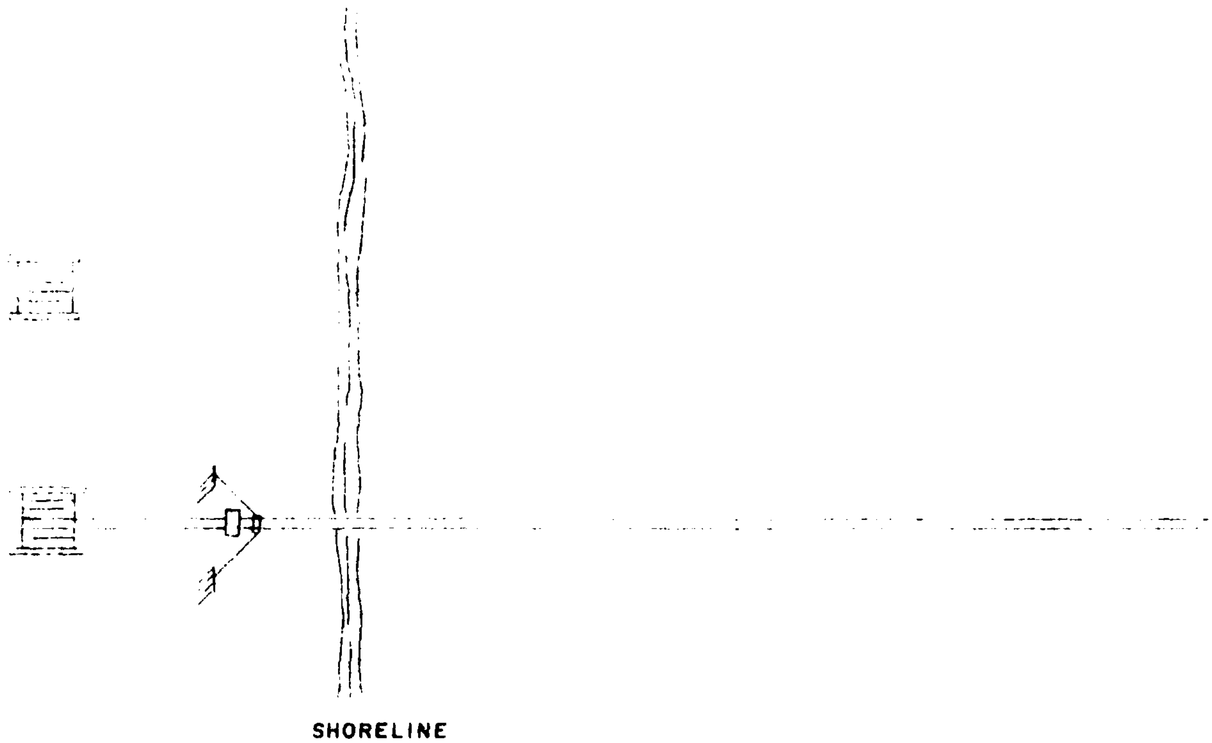
ELEVATION

PULLING :

— SET HOLDBACK TENSION. REPLACE EMPTY REEL WITH ANOTHER PIPE REEL.

FIGURE 6-8E
TYPICAL ONSHORE REEL

DRAWN BY: M. RICH	APPROVED: B.W.M.
DATE: APRIL 27, 1981	SCALE: NONE
DMJM	8413-01-01



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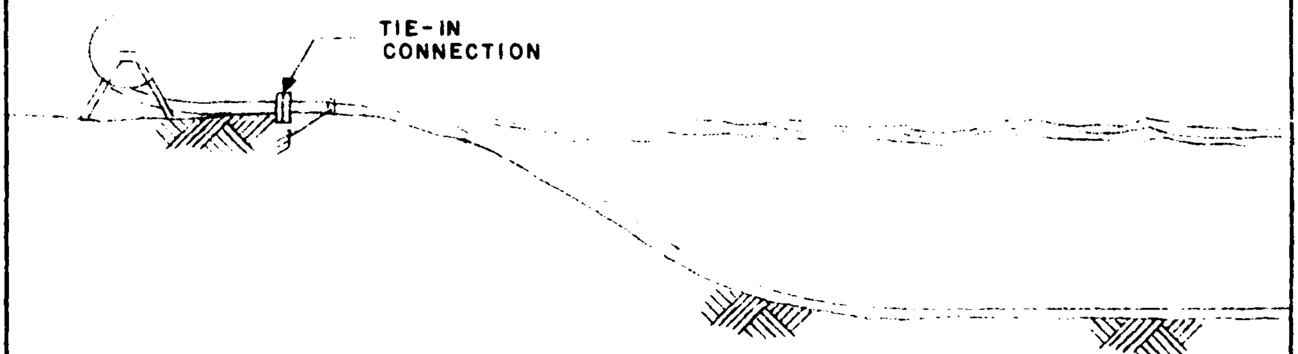
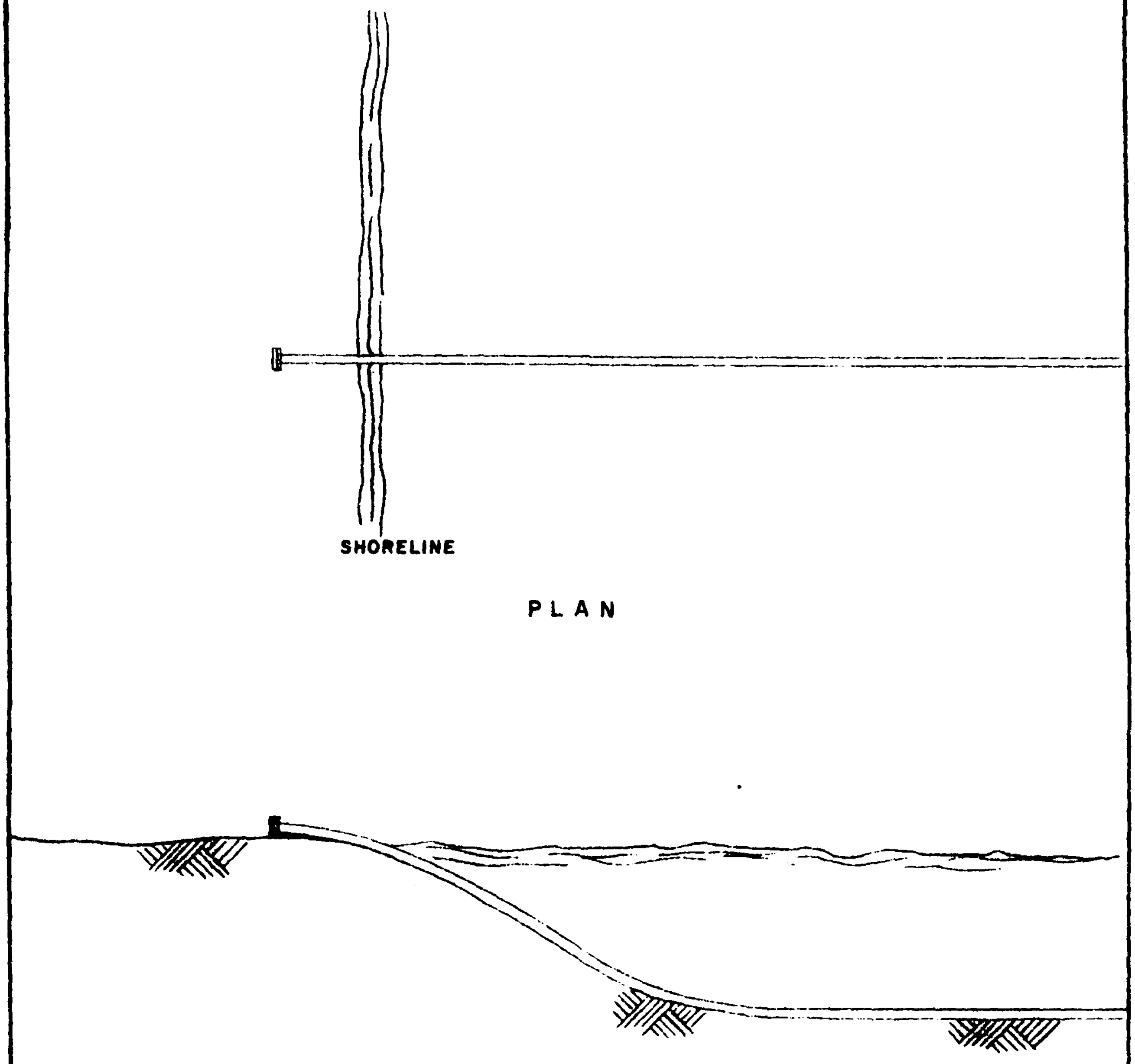


ELEVATION

JOINING & PULLING:

- JOIN PIPE ENDS. RELEASE HOLDBACK TENSION AND RESUME PULLING OPERATIONS AS PREVIOUSLY OUTLINED UNTIL ALL PIPE IS LAID.

FIGURE 6-8F TYPICAL ONSHORE REEL	
DRAWN BY: M. RICH	APPROVED: B. W. M.
DATE: APRIL 27, 1981	SCALE: NONE
DMJM	8413-01-01



COMPLETION:

- STABILIZE PIPELINE AS REQUIRED.
- RESTORE SITE.
- DEMOBILIZE EQUIPMENT AND PERSONNEL.

FIGURE 6-8G

TYPICAL ONSHORE REEL

DRAWN BY: M. RICH	APPROVED: B.W.M.
DATE: APRIL 27, 1981	SCALE: NONE
DMJM	8413-01-01

d) Positioning system for maintaining alignment.

Pipe materials which are most compatible with the reel method include:

a) Steel.
b) Plastic (HDPE only).
c) Hose.
d) Flexible.

Advantages of a reel barge method are:

a) All joining of the pipe, up to the capacity of the reel, is completed on land, thus reducing the amount of overwater work.
b) Speed of installation in the field is greater than other pipelaying methods.
c) Due to the speed of laying, the operations are less vulnerable to inclement weather.

Disadvantages of the reel barge method are:

a) Presently restricted to a maximum pipe size of 8 to 12 inches.
b) Definite limits to the length of pipe that can be handled on one reel. If length of line is greater than the capacity of the reel either the barge must come to shore to re-reel another pipe string or a pipe reel transfer must be made at sea.
c) Types of coatings which can be used on steel pipe are limited. Concrete coating cannot be used.

6.1.3 Float, Connect, And Sink

Pipe sections are joined onshore to form long pipe strings, fitted with bouyancy devices, and launched. A tug is used to tow the floating pipe strings to the jobsite. Pipe strings are pulled onto or alongside a tie-in barge and the strings are connected onboard. Figure 6-9 shows a typical tie-in configuration.

After connection, the pipeline is passed over the barge as it advances forward along the pipeline route. The pipeline is lowered to the seabed by either spaced bouys or a conventional tensioning and stringer system.

This method is a combination of the surface pull method (to transport the pipe strings to the site) and the lay barge method (to lay the pipe on the seabed).

Sequential steps of this method include:

a) Mobilization:
   1. Personnel
   2. Equipment

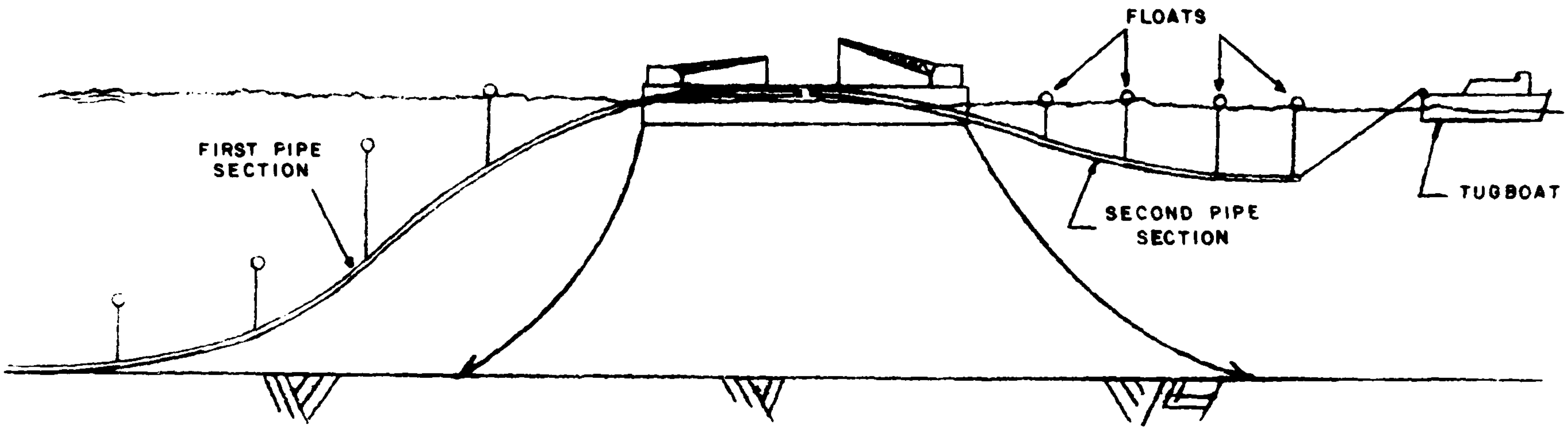


FIGURE 6-9 FLOAT, CONNECT, & SINK PIPE CONFIGURATION	
DRAWN BY: J. STEARNS	APPROVED: J.P.S.
DATE: FEB. 23, 1981	SCALE: NONE
DMJM	8413-01-01

3. Materials

b) Equipment Rig-Up

c) Site Preparation:

1. Onshore
2. Offshore

d) Construction:

1. Prepare pipe for joining at remote assembly site
2. Join pipe to form pipe strings
3. Inspect and test pipe joints
4. Field coat pipe joints (as applicable)
5. Pretrench ditch (as applicable)
6. Attach buoyancy devices to pipe string
7. Pull pipe string into the sea, and tow on or below the surface to the bow of the connection barge
8. Pull pipe onto the barge
9. Remove buoyancy devices
10. Pipe string is laid from the barge stern in a conventional lay barge method
    a. This method maintains a holdback tension on the pipeline as it leaves the barge to control stress levels in the pipeline in the overbend and underbend areas of the suspended pipeline before it touches the seabed
    b. The conventional float, connect, and sink method employs auxiliary buoyancy devices attached to the pipeline as it leaves the barge to control stress levels. Controlled flooding of the buoyancy devices may be used to allow the pipe to sink to the seabed
11. Stop the pipe lay when pipe string reaches its end
12. Repeat Steps 6., 7., 8., 9.
13. Join pipe string
14. Inspect pipe and test string connections
15. Field coat pipe connection (as applicable)
16. Go to Step 10. and repeat steps until pipeline is installed
17. Post trench ditch (as applicable)
18. Backfill pipeline (as applicable)
19. Test pipeline for integrity

e) Site Restoration

f) Equipment De-Rig

g) Demobilization:

1. Personnel
2. Equipment
3. Materials

Equipment requirements include the tie-in barge, tugs, numerous floatation buoys, and an onshore fabrication yard and launchway.

Pipe materials which are most compatible with this method include:

a) Steel.
b) Plastic (HDPE only).

Advantages of the Float, Connect, and Sink method are:

a) Less overwater work. Most pipe fabrication is in an onshore yard.
b) Fewer offshore personnel required than conventional lay barges because only one tie-in connection is required per pipe string.
c) Increased laying speed.

Disadvantages of the Float, Connect, and Sink method include:

a) Long pipe strings are exposed to winds and waves during tow to offshore job site.
b) Limited to calm weather for offshore tie-ins between pipe strings.
c) Errors in buoy spacing and buoy connection may cause pipe string failure.

Variations of the method include making connections alongside the tie-in barge rather than having the entire pipe string pass over the barge. For UCT/NMCB resources this variation is more resource efficient than connecting on the barge. This is particularly true for nearshore applications in shallow water. Lowering the connected pipe strings to the seabed is the most critical operation.

6.1.4 Directional Drilling

A relatively new and innovative concept is a directionally controlled, near horizontal drilling process that has been developed by Titan Contractors Corporation. Although the largest market for this technique is in the installation of river crossings, drilled installation of pipelines up to a length of 2500 feet and 42 inches in diameter can be done. The procedure for offshore installations is the same as for river crossings. The only difference is the drill rig is mounted on a barge located offshore. The directionally controlled drilling operation eliminates the need for either pre-dredging, preblasting, post-trenching, and backfilling since the pipe is installed in an inverted arc well below the soil surface. The depth of cover can be 25 to 100 feet of undisturbed soil over the pipeline.

Sequential steps of the Drilling Method using the normal "pullback" procedure include:

a) Mobilization:
   1. Personnel

2. Equipment
3. Materials

b) Equipment Rig-Up

c) Onshore Site Preparation:

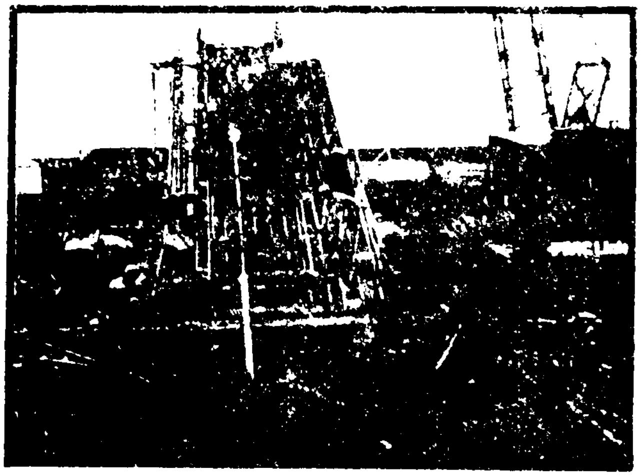
d) Construction:
1. Rig-up and align barge-mounted drilling machine at offshore end of the pipeline route
2. String pipe for joining onshore
3. Join pipe to form pipe strings
4. Inspect pipe joint
5. Field coat pipe joint (as applicable)
6. Prepare pipe launchway/ramp
7. Drill pilot hole with the drilling machine in an inverted arc from one end of the proposed pipeline to the other; follow the 2 to 3 inch diameter pilot hole with a 5 inch diameter work string. The hole is continuously flushed and lubricated with a drilling mud as the work string is "washed over" the pilot string. Remove pilot string
8. Attach a cutter/reamer to the work string and ream the pilot hole
9. Continue reaming operations with incrementally larger reamers until hole is about 6 inches larger than pipeline
10. Pull pipeline string through the hole toward the drilling machine with the work string
11. Stop pull when the end of the string reaches the end of the launchway
12. Position next string in launchway
13. Join pipe strings
14. Inspect pipe string connection
15. Field coat pipe connection (as applicable)
16. Go to Step 10. and repeat steps until pipeline is installed
17. Test pipe for integrity

e) Site Restoration/Clean-up

f) Equipment De-rig

g) Demobilization:
1. Personnel
2. Equipment
3. Materials

The specially designed drill rig and bit are shown in Figures 6-10 and 6-11. The rig is disassembled into several components for highway transportation and then reassembled on the location set during the pre-construction survey. The rig is a self-contained hydraulic power drilling unit which travels up and down a ramp. The ramp is set at a predetermined angle which is determined during the initial design of the pipeline profile.



[illegible]RE 6-10

[illegible] DRILLING MACHINE

[illegible] RIVER [illegible] INGS [illegible] CONTRO[illegible] HORIZONTA[illegible] BROCHURE [illegible] REACHING & PATE[illegible] CONSTRUCTION COMPAN[illegible] RIVER CROSSING [illegible]

[illegible] APPROVED [illegible]

SCALE NONE

DMJM

[illegible]

RIG WITH BIT

BIT EXITS ON OPPOSITE BANK

* FROM "RIVER CROSSINGS DIRECTIONALLY CONTROLLED HORIZONTALLY DRILLED" BROCHURE, READING & BATES CONSTRUCTION COMPANY, RIVER CROSSING DIVISION, HOUSTON, TEXAS

FIGURE 6-11 DIRECTIONAL DRILLING MACHINE *	
DRAWN BY: M. RICH	APPROVED: J.P.S.
DATE: FEB 24, 1981	SCALE: NONE
DMJM	8413-01-01

The first stage in construction is the drilling of a 2 to 3 inch diameter pilot hole beneath the pipeline route centerline, following the pre-planned course as closely as possible. The drill bit is powered by an in-hole hydraulic motor attached to the end of a non-rotating drill string. The drill string is composed of lengths of lightweight, high strength, threaded drill pipe. The in-hole hydraulic motor is attached to a curved section of pipe called a bent sub. This unique feature of bit rotation without pipe rotation and the bent sub makes it possible to achieve the directional control required to produce a curved hole.

As the drill progresses downhole, the drill bit is deviated from a straight path in the direction of the bend, thereby creating a curved hole. The actual shape and direction of the hole depends on several factors. These factors include the composition of the material through which the drill is passing, the amount of thrust applied to the drill string, the speed of the drill motor, and the angle of the bent sub.

A pipe spread is set up on the opposite side from the drill rig where the pipeline is joined together in strings. If space permits, the entire line is pre-assembled into one continous unit, but more often it is made up into several long sections. In either case, the pre-assembly process facilitates pressure testing, a procedure normally conducted while the pilot hole is being drilled.

If a larger diameter hole is necessary, a reaming cutter is attached to the work string. The work string and reamer are pulled toward the drill rig. String joints are removed from this end as others are attached to the tail of the work string as the reamer advances. This operation is repeated using incrementally larger reamers until the desired hole diameter is obtained. Drilling mud is pumped through the string to wash cuttings from the hole and to reduce friction.

Drilling operations may be performed from an onshore site to a point offshore, or the drilling rig may be placed on a barge and the operations executed from offshore to a point onshore. The latter configuration is considered as the normal procedure. The accuracy of exiting the ground at the designated point on site has been approximately 3 feet.

The primary element which limits the length of the installation is frictional resistance of the pipe-soil interface. This is basically comprised of the type and condition of the soil and the strength of the pipe material. The pipe must resist the pulling forces required to position the pipeline in the hole.

The drilled hole will remain open longer in clay type soils and requires less force for pipe pulling than sandy soils.

Steel is the only pipe material which has been used with this method.

Another limiting factor is water depth. Offshore drilling operations have been performed in water depths of about 30 feet or less. The drill rig requires a stable platform for working such as a spud barge. Also, the drill string requires support from the soil surrounding it to prevent buckling as longitudinal forces are applied for advancing the drill.

Advantages of using this method for pipeline installations include:

- a) Pipeline is not subject to damage from anchors, erosion, or dredging operations.
- b) Construction may be maintained year around since weather and sea conditions generally have no effect on the installation.
- c) Waterway traffic is not exposed to navigational hazards or interruptions.
- d) Very little earth is disturbed along the pipeline route as compared to trenching or dredging operations.
- e) The onshore site and the sea-bottom remain almost undisturbed.
- f) Weight coated pipe is not necessary.
- g) Over-water work is virtually eliminated.

Disadvantages include:

- a) Special equipment is necessary for this method. The equipment is protected by several patents, also.
- b) Maximum pipeline lengths are limited at this time to about one-half mile.
- c) Costs are high.
- d) Applicable in shallow water only, maximum depth of about 30 feet.

6.2 ONSHORE ASSEMBLY, SUBSURFACE CONNECTION

6.2.1 Float, Sink, And Connect

Individual pipe strings (100 to 1000 feet long) are assembled at an onshore fabrication site, outfitted with buoys, launched into the sea, and towed to the job site. The pipe strings are then aligned, sunk (usually by flooding), and connected on-bottom by divers. This method is often used when the onshore landing site for the pipeline is impractical for pipe fabrication. The length of pipe strings depend on the expected sea conditions, pipe size, pipe weight, and the lifting capacity of the on-site crane.

Sequential steps of the Float, Sink, and Connect Method are:

a) Mobilization:
   1. Personnel
   2. Equipment
   3. Materials
b) Equipment Rig-Up
c) Site Preparation:
   1. Onshore
   2. Offshore
d) Construction:
   1. Prepare pipe for joining at remote assembly site
   2. Join pipe to form pipe strings
   3. Inspect and test pipe joints
   4. Field coat pipe joints (as applicable)
   5. Pretrench ditch (as applicable)
   6. Attach buoyancy devices to pipe string
   7. Pull pipe string into the sea and tow to job site
   8. Position pipe on designated right-of-way centerline
   9. Sink pipe to seabed by controlled flooding or release of buoyancy devices. Lowering pipe to the seabed and rough alignment operations are provided by barge cranes or winch lines from barges. The pipe string ends may be overlapped slightly preparatory to final alignment and joining
   10. Join pipe strings on seabed
       a. For single joints of pipe, like cast iron or RCP, a pipe alignment frame is used
       b. For pipe strings a pipe alignment frame and/or a crane barge is used to pull the pipe slack out for connection
   11. Go to Step 6. and repeat steps until pipeline is installed
   12. Post-trench ditch (as applicable)
   13. Test pipeline for integrity
   14. Backfill pipeline (as applicable)
e) Site Restoration
f) Equipment De-Rig
g) Demobilization:
   1. Personnel
   2. Equipment
   3. Materials

Equipment requirements are:

a) Onshore pipeline fabrication facility. This should be near the water so the sections can be easily launched.
b) Tugs for towing pipe strings.
c) Crane barge, barge winch lines, or similar equipment for positioning pipe strings at offshore job site.

d) Pipe handling/alignment frame for final alignment and tie-in of pipe strings (optional).

Pipe materials which are most compatible with this method include:

a) Steel.
b) Plastic (flanged connections).
c) Cast Iron (single joints only).
d) RCP (single joints only).

Advantages of this method include:

a) Limited offshore fabrication time. Most work is done onshore under protected conditions, except in case of single joint connections.
b) Limited marine equipment requirements.

Disadvantages of this method include:

a) Potential for damage to pipe strings during tow.
b) Underwater connections are more difficult to make and more time consuming.
c) Vulnerable to severe weather during final connection.

For pressure tight pipelines the on-bottom connection is an important element. As the pipeline diameter increases, the alignment of the two pipe ends becomes more difficult because the pipe is heavier and more rigid. Divers must have some lifting assistance. This can be provided by a crane or winch on the support barge or by a bottom supported handling frame. Cranes or winches on floating barges require calm weather conditions for the delicate pipe connection operation. Some recent projects have used alignment or handling frames with built-in hydraulic winches operated by the divers. Because of their relative ease of deployment, light weight and versatility, these frames could be easily adaptable to near shore pipeline installations. A further discussion is included in Chapter 7.

6.2.2 Bottom Tow And Connect

This method is the same as Float, Sink, and Connect (6.2.1) except the pipe strings are pulled along the seabed rather than on the surface. Pipe strings are towed to the site, aligned, and connected by divers.

Sequential steps for this method are the same as in 6.2.1.

Equipment requirements for this method are the same as in 6.2.1.

The additional advantage of the Bottom Tow and Connect method over the Float, Sink, and Connect method is the reduction in

exposure to surface sea conditions during towing and positioning.

A disadvantage is the possibility of damage to the pipe coating during the towing operation and the requirement that the tow route be thoroughly surveyed and obstacle-free.

An off-bottom (2 to 5 feet) tow could be substituted for the bottom tow but DMJM was unable to find a project which had used this concept.

6.3 OFFSHORE ASSEMBLY, SURFACE CONNECTION

6.3.1 Lay Barge

A lay barge is a floating pipe assembly facility. It maintains its position and moves itself along the pipeline route by a multiple-point (6 to 12) anchoring system. Tugs are used to move the anchors as the barge progresses along the pipeline route. Coated pipe is brought from shore on flat deck transport barges and transferred to storage racks on the lay barge by the lay barge crane. Sections of pipe are progressively joined together in an assembly line manner. The pipe progresses from storage racks to a line-up station, through the joining stations, radiography station, joint coating station (as applicable), and then over the stern into the water. The barge is advanced when each joint connection is finished such that the barge is pulled from underneath the pipeline allowing the pipeline to sink to the bottom. A long pontoon (150 to 600 feet), called a "stinger", supports the pipe as it leaves the lay barge. Figure 6-12 shows the general laying configuration.

The rate at which pipe is layed is determined by the size of pipe, the number of joining stations, and the length of the pipe used. The last two factors are limited by the length of the barge.

Lay barges are fully self-contained with quartering and messing facilities provided onboard. Pipelaying proceeds 24 hours per day with each crew working 12 hour shifts.

Sequential steps of the Lay Barge installation are:

a) Mobilization:
   1. Personnel
   2. Equipment
   3. Materials
b) Equipment Rig-Up
c) Transport pipe from coating yard to offshore job site
d) Construction:
   1. Pretrench shore approach (if applicable)
   2. Position lay barge

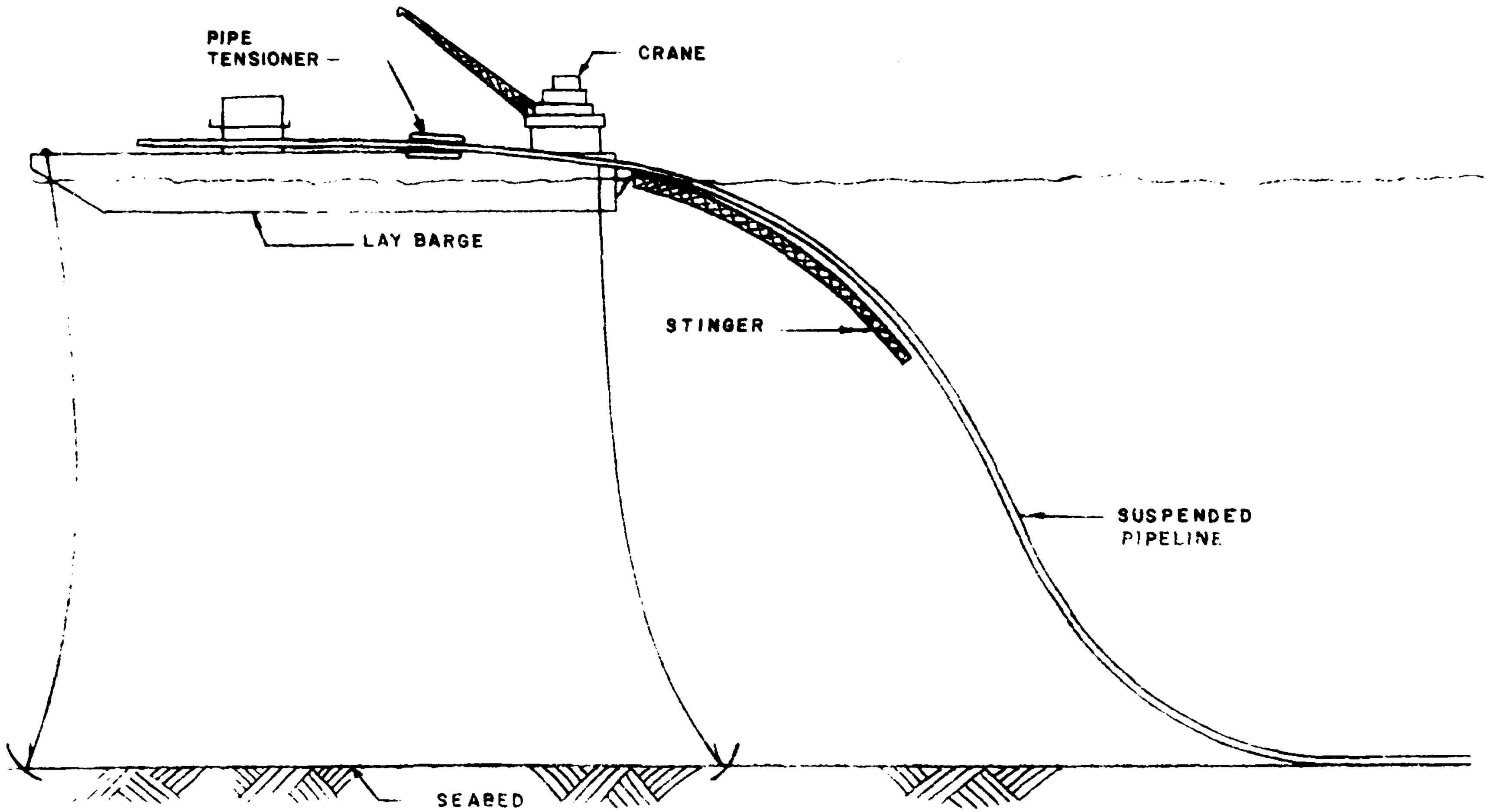


FIGURE 6-12

LAY BARGE CONFIGURATION

DRAWN BY: J. DENTON	APPROVED: J. P.S.
DATE: FEB. 10, 1981	SCALE: NONE
DMJM	8413-01-01

3. Transfer pipe section from storage rack to line-up station and set up anchoring system to anchor free end of pipe string
4. Join pipe sections to pipeline
5. Inspect pipe joint
6. Field coat pipe joint (as applicable)
7. Launch pipeline by moving barge forward until the end of the pipe reaches the end of the line-up station
8. Go to Step 3., and repeat steps until pipeline is installed
9. Post trench ditch (as applicable)
10. Test pipeline for integrity
11. Backfill pipeline (as applicable)

e) Site Restoration
f) Equipment De-Rig
g) Demobilization:
   1. Personnel
   2. Equipment
   3. Materials

Major equipment elements are:

a) Barge
b) Stinger
c) Welding system
d) Tensioners
e) Tugboats
f) Logistic support

<u>Barge.</u> Barge length, width, and depth will vary with the location and application. Those designed for operation in shallow water and protected environments may be 140 to 200 feet long. Those designed for deep water, rough environments are from 300 to over 600 feet long. Anchoring systems must be designed for the specific environments.

<u>Stinger.</u> The stinger is a long, slender, buoyant structural member attached to the stern of the barge. It supports the pipeline for part or all of the distance from the surface to the sea bottom. It can be straight, curved, or articulated and varies in length from 100 to 600 feet. Stingers are usually hinge connected to the barge. Some modern barges, designed for use in rough weather, have short truss type stingers which are rigidly connected to the barge stern. Articulated stingers have buoyant chambers which can be flooded to control curvature and departure angle (slope) of the pipeline.

<u>Welding system.</u> Conventional arc welding machines are common on most barges. Pipeline welding is usually a multiple (3 to 5) pass operation. On a lay barge the first weld pass is performed at the line-up station. The barge moves forward one pipe length and the second pass is added at the next welding

station. A barge will have as many welding stations as required to complete the weld. This assembly line process speeds up the laying operation. A few modern barges are equipped with automatic welding machines.

Tensioners. Tensioning devices are used to apply holdback or axial tension to the pipeline. Their purpose is to reduce the bending in the unsupported pipe span between the end of the stinger and the seabed. Tensioners are usually rubber-tired or tracked devices driven by hydraulic motors.

Tugboats. Two tugs are usually necessary to attend the lay barge and move its anchors along the pipeline route.

Logistic support. A crewboat is used to transfer personnel, food, and other consumable supplies. Pipe transport barges and the attending tugs are also a part of the logistic support.

Steel is the only pipe material which has been used with this method.

Advantages of the lay barge method are:

a) Flexibility - Lay barges can lay pipe from 2 to 60 inches in diameter, in water depths from 20 feet to over 1000 feet, and in a wide variety of weather conditions.
b) If a pipe failure occurs during laying, the lay barge can, in most cases, repair the damage without mobilizing additional equipment.

Disadvantages of the lay barge are:

a) All work is done offshore, making the entire operation weather dependent. Operations must be suspended for most barges in 6 to 8 foot seas.
b) It is too expensive to mobilize and set up for short, nearshore pipelines.

Numerous variations of the lay barge have been used through the years, some successfully and some not. For instance, one concept substituted buoys for the stinger. Various buoy attachment and detachment ideas have been designed including a variable lift buoy which decreased in volume (and therefore lift force) as it descended to deeper water.

One proprietary concept called Flexifloats has good potential for use by the UCT/NMCB on nearshore pipeline installation projects. As the name implies, its primary advantage is flexibility. Flexifloats are small, steel hull barge units which can be assembled in a variety of shapes to handle almost any offshore construction task, including shallow water pipe laying. These are discussed further in Chapter 7 and Appendix G.

6.4 OFFSHORE ASSEMBLY, SUBSURFACE CONNECTION

6.4.1 Trestle Method

The trestle method of construction employs a structural causeway built as an extension of the onshore site. This method is primarily used for short and heavy pipelines, through severely turbulent surf zones, or where extreme precision is required for pipe lowering-in operations.

Sequential steps of the Trestle Method are:

a) Mobilization:
   1. Personnel
   2. Equipment
   3. Materials

b) Equipment Rig-Up

c) Site Preparation:
   1. Onshore
   2. Offshore

d) Construction:
   1. Construct trestle seaward from shore complete with crawler cranes, gantry cranes, trolleys, or other pipe handling and lowering devices
   2. Pretrench ditch (as applicable)

      NOTE: The following steps assume the use of a pipe frame for handling multiple joints or pipe strings. If a joint-by-joint method is used instead, go to step 7. (substitute the word "joint" for "string")
   3. String pipe for joining
   4. Join pipe to form pipe strings
   5. Inspect and test pipe joints
   6. Field coat pipe joints (as applicable)
   7. Position a pipe string in the lowering device on the trestle
   8. Lower the pipe string to the seabed
   9. Join the pipe string (under water)
   10. Inspect pipe string connection
   11. Field coat pipe connection (as applicable)
   12. Go to Step 7 and repeat steps until pipeline is installed
   13. Post trench ditch (as applicable)
   14. Backfill pipeline (as applicable)
   15. Test pipeline for integrity
   16. Disassemble trestle

e) Site Restoration

f) Equipment De-Rig

g) Demobilization:
   1. Personnel
   2. Equipment
   3. Materials

The trestle or causeway is constructed from the shore into the sea. The trestle is essentially used in waters that are too shallow for pipelaying barges or where waves and surf conditions would cause considerable motion of such a floating platform. Although the trestle itself does not eliminate all wave surge problems, it does ensure that work can be done from a fixed platform.

The basic the principle behind the trestle method involves the use of "H" piles that are driven into the seabed at a prescribed longitudinal and lateral spacing. They are usually not grouted so that the piles can be retrieved later. A pile bent is made by setting beams across pairs of piles. Bolting rather than welding eases recovery upon work completion. Longitudinal beams are then laid across the pile bents, and rails for the crane/pile-drive/pipe lay carriage are finally placed to complete the structure. The carriage progressively advances seaward as it completes the pile driving and follow-up trestle erection. While the trestle is being extended by one crane, another crane can be driving sheet piling further inshore, preferably with a vibratory hammer, and/or excavating with a clamshell, preparing the seabed for the pipe laying operations.

Either one or two cranes can be used to lay the pipe. They travel along stationary track rails and straddle the pipe while carrying it. The cranes lower the pipe into place on the seabed. The pipe section is supported by two or three slings passed under the pipe.

After pipe laying and backfill/stabilization operations are completed the trestle may be dismantled using the reverse of the erection method.

Almost any diameter pipe can be installed using this method. Connection of pipe lengths is done on the seabed for most trestle method projects.

Equipment requirements are significant in that gantry cranes, and piledrivers are necessary. Also, the structural design and trestle fabrication require considerable expertise. This is not a very resource efficient method but it has the advantage of not requiring any floating equipment.

Pipe materials which are most compatible with this method include (all sizes available):

a) Steel.
b) Asbestos bonded corrogated metal.
c) Cast iron.
d) Reinforced concrete.
e) Wrought iron.

Advantages of the Trestle Method include:

a) No floating facilities required.
b) All work is done from a stable platform.
c) Adaptable to most pipe materials.

Disadvantages of the Trestle Method include:

a) Limited (by economics and practicality - not technically) to short lengths through surf zone areas.
b) Requires substantial work force, materials, and equipment, (not very resource efficient).
c) Trenching/burial of the pipeline is difficult.

Variations of the Trestle Method include:

a) Building a permanent fixed trestle, laying the pipe on the trestle and leaving it above water.
b) Using a fixed trestle as a launching ramp for a bottom pull concept.

6.4.2 Jack-Up Platform

Mobile jack-up platforms have usually been built for specific projects which have used large diameter, heavy pipe lengths, usually reinforced concrete pipe. The large, buoyant platform is floated to the site and the legs are lowered to the seabed. Large jacks are used to raise the platform out of the water thereby providing a stable work platform free from the effects of waves or currents. This is a joint-by-joint method of installation with each pipe length laid one at a time on the seabed. Connections of pipe lengths are made by divers. As each section of pipe is added to the line, the platform is moved from one location to another by jacking its buoyant deck down into the water until the entire structure is floating. It moves to the desired new position by pulling on anchor lines or by tugs. The platform is then jacked out of the water again to continue laying operations. Figure 6-13 shows a photograph of a jack-up platform used to install a large diameter pipeline. Figure 6-14 is a simplified drawing showing the platform operation. The inhaul cable/snatch block mechanism is used to exert an axial load on the pipe string to form a joint connection when utilizing a bell-and-spigot type connection. The pontoon - strongback provides support for the pipe string during lowering when a bell-and-spigot type joint is utilized.

Sequential steps of this method are:

a) Mobilization:
   1. Personnel
   2. Equipment
   3. Materials

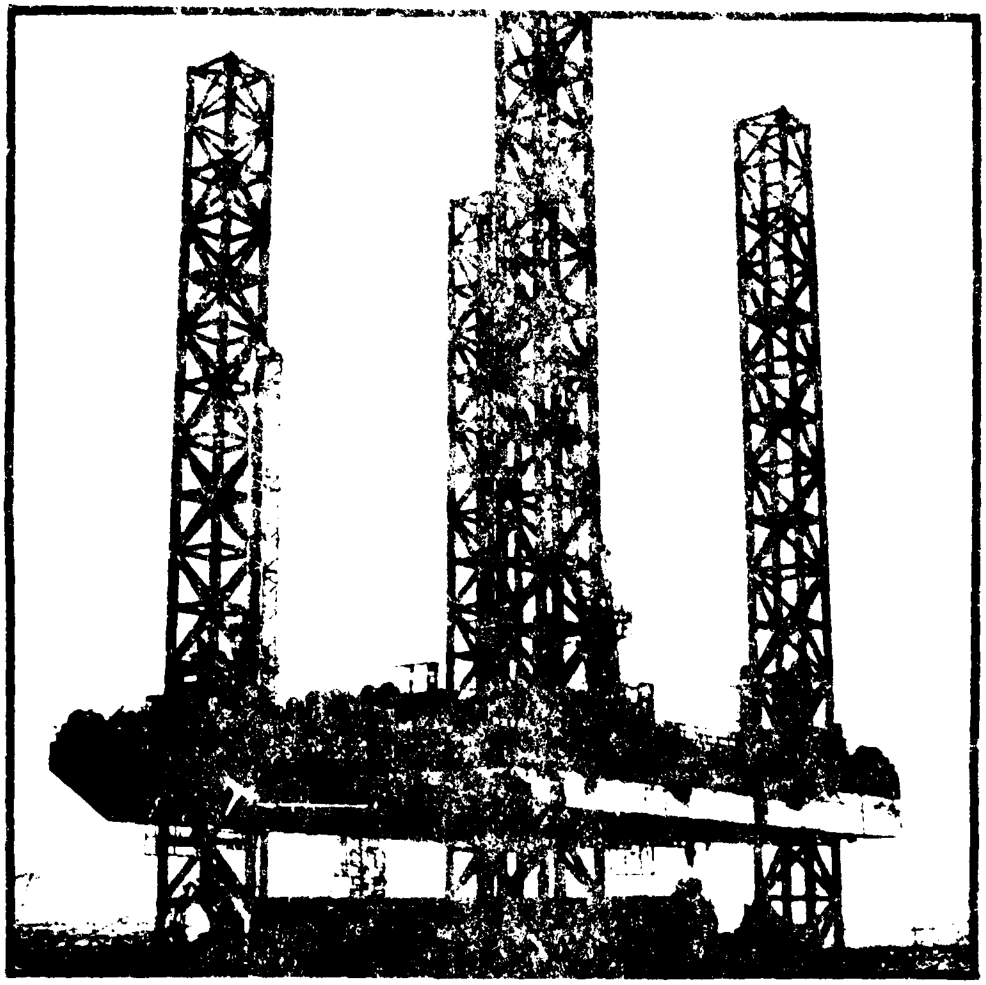


FIGURE 6-13
JACK-UP PLATFORM
IN RAISED POSITION*

DRAWN BY J. DENTON	APPROVED: J. P. S.
DATE FEB 10, 198[illegible]	SCALE: NONE
DMJM	8413-01-01

* PER PHOTOGRAPH FROM E. R. MILLER

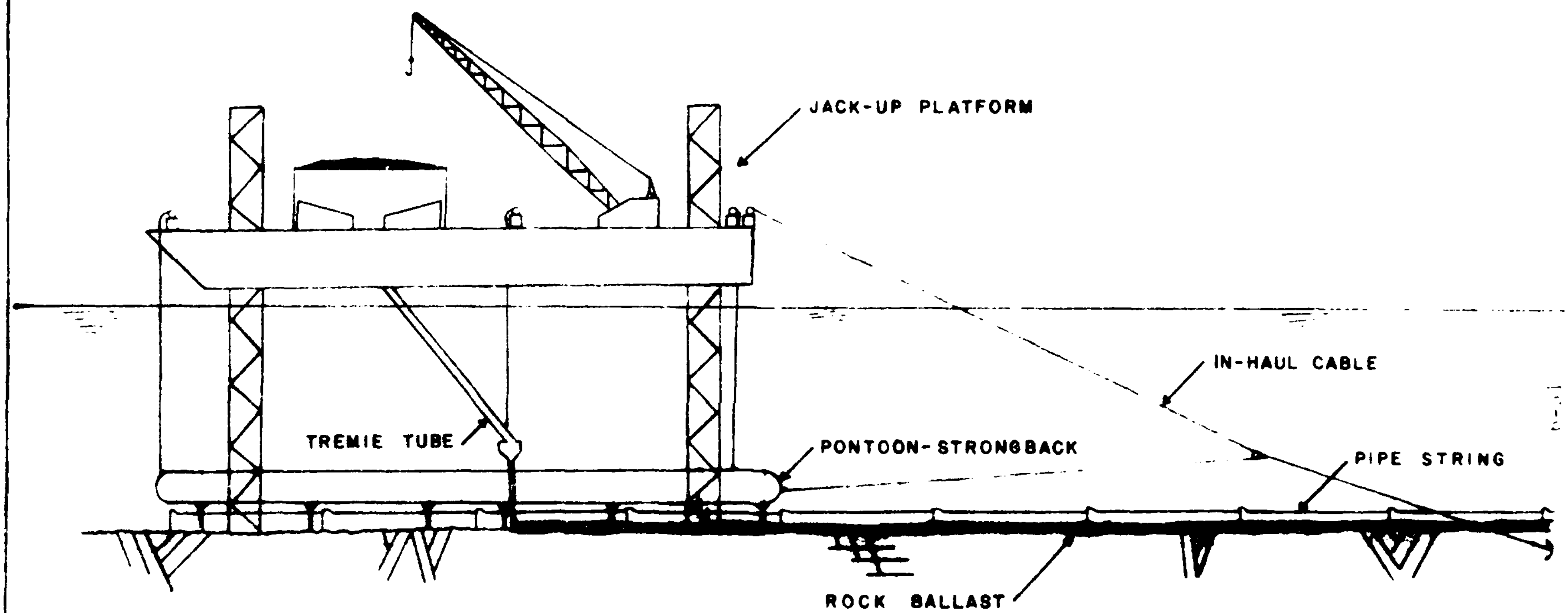


FIGURE 6-14 JACK-UP PLATFORM CONFIGURATION	
DRAWN BY: J. STEARNS	APPROVED: J.P.S.
DATE: FEB 23, 1981	SCALE: NONE
DMJM	8413-01-01

b) Equipment Rig-Up
c) Site Preparation:
   1. Onshore
   2. Offshore
d) Construction:
   1. Load pipe on support barge or on jack-up platform
   2. Pretrench ditch (as applicable)
   3. Position jack-up platform
   4. Join pipe to form short pipe segments (if applicable)
   5. Inspect and test pipe joint
   6. Field coat pipe joint (as applicable)
   7. Position short pipe segments in pipe handling frame or spreader bar with pipe slings
   8. Lower pipe to seabed
   9. Join pipe segments on seabed
   10. Go to Step 3. and repeat steps until pipeline is installed
   11. Post-trench ditch (as applicable)
   12. Test pipeline for integrity
   13. Backfill pipeline (as applicable)
e) Site Restoration
f) Equipment De-Rig
g) Demobilization:
   1. Personnel
   2. Equipment
   3. Materials

Pipe materials which are most compatible with this method include (all sizes available):

a) Steel.
b) Reinforced concrete.

Advantages of using a jack-up platform include:

a) Provides a stable work platform free from the affects of waves and currents.
b) Capable of handling large diameter, heavy pipe.

Disadvantages include:

a) Not very practical for small diameter pipe; other means are more economical.
b) Very expensive, special jack-up platform is required.

CHAPTER 7

STATE-OF-THE-ART METHODS ANALYSIS AND CONCLUSIONS

7.0 GENERAL

An analysis of the information gathered during this study allowed certain conclusions to be reached with respect to the project objectives. This chapter presents the analysis results as follows:

a) Selection of most practical pipe materials.
b) Identification of state-of-the-art methods which are presently within the UCT/NMCB capabilities.
c) Identification of state-of-the-art methods which have potential for use by the UCT/NMCB if technology is advanced (personnel and/or equipment).
d) Recommendations for further analysis.

7.1 PIPE MATERIAL ANALYSIS

Although the recommendation of pipe materials is not required by the Statement of Work, it has a definite influence on method analysis. For example, pipe material influences construction procedures which in turn influences the tools and equipment required, personnel skills required, magnitude of logistic support, operational life, project risk prediction, and allowable pipeline design criteria.

None of the methods considered are ideally suited for all pipe materials. Some methods exclude use of certain pipe materials. For instance, the reel method precludes the use of large diameter rigid pipe. Other methods were developed for a specific pipe material. An example is the lay barge which was developed specifically for welded steel pipe. In other cases, one material is simply more practical than another for a specific method.

Table 7-1 presents a summary of the pipe materials that can be used with the various methods discussed in Chapter 6. This summary assumes that a pipe joining technique will be chosen that is compatible with the method. For example, the method of joining plastic pipe for the pull method would have to be strong enough to resist the axial pull forces.

Considering the need for project flexibility, resource utilization, and pipeline dependability it is concluded that maximum emphasis should be placed on:

a) Coated steel pipe.
b) Flexible pipe (hose, Simplex, Coflexip).
c) Plastic (FRP and/or HDPE).

Table 7-1 illustrates that steel and flexible pipe materials were chosen because of their wide range of project application, and plastic pipe was chosen because its use results in efficient utilization of resources.

TABLE 7-1

SUMMARY OF PIPE MATERIALS VERSUS INSTALLATION METHODS

INSTALLATION METHODS	PIPE MATERIALS												
	Coated Steel	Flexible Coflexip	Flexible Simplex	Flexible Hose	Plastic FRP	Plastic HDPE	Aluminum	Asbestos Bonded	Corrugated Metal	Asbestos Cement	Cast Iron	Reinforced Concrete	Wrought Iron
Pull Method	X	X	X	X	X	X	X						
Reel Method	X	X	X	X		X							
Float, Connect, & Sink	X	X	X	X	X*	X*							
Directional Drilling	X												
Float, Sink, & Connect	X	X	X	X				X		X	X	X	X
Lay Barge	X												
Trestle Method	X	X	X	X				X		X	X	X	X
Jack-Up Platform	X	X	X	X				X		X	X	X	X

X indicates that the pipe material is suitable for use with the listed method.

X* indicates that extreme care must be exercised in using this combination of pipe material and construction method.

7.2 STATE-OF-THE-ART METHODS WITHIN THE UCT/NMCB CURRENT CAPABILITY

Tables 7-2, 7-3, and 7-4 present a comparative analysis of the various installation methods for the three pipe materials selected in Section 7.1. Comparing this analysis with the assessment of the UCT/NMCB capabilities, it was concluded that the following methods are within their current capabilities:

a) Pull Method.
b) Trestle Method.
c) Float, Sink, and Connect.
d) Reel Method (size limited).

It is noted that the UCT/NMCB have used the reel method to lay pipe. This involved the use of Simplex hose spooled on a large wooden reel. This constitutes the basic principles of the Reel Method. Additionally, they stock reels of small diameter flat hose, similar to fire hose listed in the Table of Allowance and maintain the capability to deploy and lay this type of flexible pipe. However, this does not meet the criteria of this study, particularly the size and pressure ranges, and operational life. Additionally, this flat hose is not conducive to transporting the full range of fluids assumed for this study.

The Reel Method addressed in this study focuses on other pipe materials and larger diameters which require more sophisticated reel system units, however, the basic methodology remains the same.

Those methods not within the UCT/NMCB capability include:

a) Lay Barge.
b) Reel Method (for large pipe).
c) Directional Drilling.
d) Jack-Up Platform.
e) Float, Connect, and Sink.

Lack of required special equipment and trained, experienced personnel are the primary reasons that these methods are beyond the UCT/NMCB's current capabilities.

7.3 STATE-OF-THE-ART METHODS WITH POTENTIAL FOR FUTURE USE

All of the methods beyond current UCT/NMCB capabilities listed in Section 7.2 have potential for developement by the UCT/NMCB, however, some are not practical to develope in a resource efficient manner. For example, directional drilling equipment, a large lay barge, or a large jack-up platform would probably require more capital investment in equipment than could be justified by the UCT/NMCB. Most barges used for the Float, Connect, and Sink method require large expenditures for acquiring the barge plus barge rig-up. Intermittent needs coupled with the shallow water, nearshore, relatively small diameter pipelines make large expenditures for this type of equipment impractical.

TABLE 7-2

COATED STEEL PIPE INSTALLATIONS

ITEM	INSTALLATION METHOD							
	PULL METHOD	REEL METHOD	FLOAT, CONNECT, & SINK	DIRECTIONAL DRILLING	FLOAT, SINK, & CONNECT	LAY BARGE	TRESTLE METHOD	JACK-UP PLATFORM
SPECIAL SKILLS	Pipeline Welders	Pipeline Welders	Pipeline Welders	Pipeline Welders	Pipeline Welders	Pipeline Welders	Pipeline Welders	Pipeline Welders
	Experienced Crews	Experienced Crews	Experienced Crews	Experienced Crews	Experienced Crews	Experienced Crews	Divers	Experienced Crews
		Reel Operator		Drilling Operator	Divers	Divers	Fabricators	Divers
							Riggers	
SPECIAL EQUIPMENT	Winches	Barge	Barge	Drilling Machine	Pipe Line-Up System	Lay Barge	Pipe Line-Up System	Pipe Line-Up System
	Launchway	Tugboat	Tugboat		Tugboat	Anchor Tug	Trestle Structure	Jack-Up Platform
	Pull Barge	Reel System	Buoy System		Buoys	Supply Barge	Cranes	
	Buoys					Tugboat		
	Tugboat							
LIMITING SITE CONDITIONS[1]	Near Vertical Shoreline	Rough Seas, Seas Greater Than 6 feet	Rough Seas, Seas Greater Than 2 feet	Rough Seas, Seas Greater Than 2 feet	Rough Seas, Seas Greater Than 4 feet	Rough Seas, Seas Greater Than 6 feet		Shallow Water Less Than 20 feet (Platform Draft)
	No Onshore Space	Shallow Water Less Than 20 feet (Reel Barge Draft)		Deep Water Greater Than 30 feet		Shallow Water Less Than 20 feet (Barge Draft)		
				Distance				

LIMITING SITE CONDITIONS[1]	Near Vertical Shoreline No Onshore Space	Rough Seas, Seas Greater Than 6 feet Shallow Water Less Than 20 feet (Reel Barge Draft)	Rough Seas, Seas Greater Than 2 feet	Rough Seas, Seas Greater Than 2 feet Deep Water Greater Than 30 feet Distance Limited	Rough Seas, Seas Greater Than 4 feet	Rough Seas, Seas Greater Than 6 feet Shallow Water Less Than 20 feet (Barge Draft)		Shallow Water Less Than 20 feet (Platform Draft)
PIPE DIAMETER LIMITS[2] (inches)	4 - 24	4 - 12	4 - 24	4 - 24 Distance Limited	4 - 24	4 - 24 Welded, Metallic	4 - 24	4 - 24
OFFSITE LOGISTIC SUPPORT[3]		Pipe Delivery Fabrication Yard	Fabrication Yard		Fabrication Yard	Pipe Delivery Catering		Pipe Delivery
OPERATIONAL LIFE[4]	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
PREDICTION RISK[5]	Low	Low	Moderate	Low	Moderate	Low	Low	Moderate

SEE: NOTES TO TABLES

2

TABLE 7-3

FLEXIBLE PIPE INSTALLATIONS

ITEM	INSTALLATION METHOD							
	PULL METHOD	REEL METHOD	FLOAT, CONNECT, & SINK	DIRECTIONAL DRILLING	FLOAT, SINK, & CONNECT	LAY BARGE	TRESTLE METHOD	JACK-UP PLATFORM
SPECIAL SKILLS	Experienced Crews	Experienced Crews Reel Operator	Not Applicable For This Pipe Mat'l.	Not Applicable For This Pipe Mat'l.	Not Applicable For This Pipe Mat'l.	Not Practical For This Pipe Mat'l.	Not Practical For This Pipe Mat'l.	Not Practical For This Pipe Mat'l.
SPECIAL EQUIPMENT	Winches Launchway Pull Barge Buoys Tugboat	Barge Tugboat Reel System						
LIMITING SITE CONDITIONS[1]	Near Vertical Shoreline No Onshore Space	Rough Seas, Seas Greater Than 6 feet Shallow Water Less Than 20 feet (Reel Barge Draft)	Not Applicable For This Pipe Mat'l.	Not Applicable For This Pipe Mat'l.	Not Applicable For This Pipe Mat'l.	Not Practical For This Pipe Mat'l.	Not Practical For This Pipe Mat'l.	Not Practical For This Pipe Mat'l.

LIMITING SITE CONDITIONS[1]	Near Vertical Shoreline	Rough Seas, Seas Greater Than 6 feet	Not Applicable For This Pipe Mat'l.	Not Applicable For This Pipe Mat'l.	Not Applicable For This Pipe Mat'l.	Not Practical For This Pipe Mat'l.	Not Practical For This Pipe Mat'l.	Not Practical For This Pipe Mat'l.
	No Onshore Space	Shallow Water Less Than 20 feet (Reel Barge Draft)						
PIPE DIAMETER LIMITS[2] (inches)	4 - 12	4 - 12						
OFFSITE LOGISTIC SUPPORT[3]		Pipe Delivery						
		Fabrication Yard						
OPERATIONAL LIFE[4]	High	High	Not Applicable For This Pipe Mat'l.	Not Applicable For This Pipe Mat'l.	Not Applicable For This Pipe Mat'l.	Not Practical For This Pipe Mat'l.	Not Practical For This Pipe Mat'l.	Not Practical For This Pipe Mat'l.
PREDICTION RISK[5]	Low	Low						

SEE: NOTES TO TABLES

2

TABLE 7-4

PLASTIC PIPE INSTALLATION

ITEM	INSTALLATION METHOD							
	PULL METHOD	REEL METHOD	FLOAT, CONNECT, & SINK	DIRECTIONAL DRILLING	FLOAT, SINK, & CONNECT	LAY BARGE	TRESTLE METHOD	JACK-UP PLATFORM
SPECIAL SKILLS	Butt Fusion Machine Operator (HDPE) Experienced Crews	Butt Fusion Machine Operator (HDPE) Experienced Crews Reel Operator	Experienced Crews	Not Applicable For This Pipe Mat'l.	Experienced Crews Divers	Not Practical For This Pipe Mat'l.	Fabricators Riggers Divers	Experienced Crews Divers
SPECIAL EQUIPMENT	Fusion Machine (HDPE) Winches Launchway Pull Barge Buoys Tugboat	Fusion Machine (HDPE) Reel System Tugboat Barge	Barge Tugboat Buoy System		Line-Up System Buoys Tugboat		Line-Up System Trestle Structure Crane	Line-Up System Jack-Up Platform
LIMITING SITE CONDITIONS[1]	Near Vertical Shoreline	Rough Seas, Seas Greater Than 6 feet	Rough Seas Seas Greater Than 2 feet	Not Applicable For This Pipe Mat'l.	Rough Seas Seas Greater Than 4 feet	Not Practical For This Pipe Mat'l.		Shallow Water Less Than 20 feet (Platform Draft)

	Pull Barge Buoys Tugboat	Barge						
LIMITING SITE CONDITIONS[1]	Near Vertical Shoreline No Onshore Space	Rough Seas, Seas Greater Than 6 feet Shallow Water Less Than 20 feet (Reel Barge Draft)	Rough Seas Seas Greater Than 2 feet	Not Applicable For This Pipe Mat'l.	Rough Seas Seas Greater Than 4 feet	Not Practical For This Pipe Mat'l.		Shallow Water Less Than 20 feet (Platform Draft)
PIPE DIAMETER LIMITS[2] (inches)	4 - 24	4 - 12 HDPE Only	4 - 12		4 - 24		4 - 24	4 - 24
OFFSITE LOGISTIC SUPPORT[3]		Pipe Delivery Fabrication Yard	Pipe Delivery Fabrication Yard		Pipe Delivery Fabrication Yard			Pipe Delivery
OPERATIONAL LIFE[4]	Moderate	Moderate	Moderate	Not Applicable For This Pipe Mat'l.	Moderate	Not Practical For This Pipe Mat'l.	Moderate	Moderate
PREDICTION RISK[5]	Low	Low	High		Moderate		Low	Low

SEE: <u>NOTES TO TABLES</u>

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Methods which have the most potential for modification to the UCT/NMCB needs are:

a) Lay Barge (scaled down).
b) Reel Method (for large pipe).
c) Jack-Up Platform (scaled down).

The use of "Flexifloats" could provide both a scaled down lay barge and scaled down jack-up platform capability. Flexifloats are modular units which can be assembled in a variety of configurations. Basic Flexifloat barge modules are 10 feet x 40 feet. Half units (10 feet x 20 feet), quarter units (10 feet x 10 feet), bow units tapered for towing, and a variety of other shapes are available. Also available, in modular form for use with the Flexifloats, are anchor winch units, jack-up spuds for shallow water, pipe support units, and other specialized units. Barge units are interlocked together with a patented connector.

With a full complement of Flexifloats, it would be possible to arrange the modules into a:

a) Jack-up work platform in shallow water where onshore work space was not available.
b) Center-slot lay barge for shallow water.
c) Dredge barge.
d) Winch barge for bottom pull method.
e) Diving support barge with crane for assisting underwater pipe connection activity.
f) Crane barge.
g) Transport barge.

Appendix G contains several pages which describe the Flexifloat concept. These units can be leased or purchased.

It is possible that the standard Navy, pontoon cans (5 feet x 5 feet x 7 feet) could be configured into the required platforms.

An additional advantage of Flexifloats is their adaptability for use in other offshore construction or transport activities of the UCT/NMCB.

One of the most resource efficient methods of laying 12 inch diameter and smaller pipelines is the reel method. Reel barges used by the offshore oil and gas industry have been designed for high pressure steel pipe or the ultra high pressure flexible pipe (Coflexip). Both steel pipe and Coflexip require a large onshore fabrication facility to handle the pipe. Steel pipe must be stressed to yield when bent (permanent set) during the spool reeling-up operation. In turn, this requires straightening frames and rollers on the reel barge to remove this per-manent set before the line is laid on the seabed.

Since the internal pressure requirements for this study are comparatively low, it appears reasonable to assume that one of the lower pressure rated, but flexible pipe materials could be combined with

the reel concept. Although some manufacturers claim to have hose or flexible pipe up to 6 or 8 inch diameter, it will take some additional development and engineering efforts to refine the combined concepts to meet the UCT/NMCB needs. By using flexible pipe or hose, a substantial reduction can be realized in equipment and personnel needs, and technical expertise requirements at the job site.

7.4 STATE-OF-THE-ART CONCLUSIONS AND RECOMMENDATIONS

For maximum utilization of available resources and minimum risk the UCT/NMCB should attempt to limit the pipe diameters to 12 inches maximum. This can be done through design by using pumps to increase flow rather than larger lines, or by installing multiple lines rather than one large line.

Coated steel pipe provides the widest range of utilization but requires qualified welders for joining. Plastic pipe is most resource efficient due to the relatively non-technical joining methods and its light weight.

For immediate projects where shore conditions allow, the pull method of installation should be the preferred method. Either the SEACON or a similarly equipped barge could be used as an offshore pull barge. Pipe materials could be steel (if qualified welders are available) or HDPE plastic pipe. Careful attention must be given to stability and mechanical protection.

For immediate projects where there is no on-site space for onshore fabrication, the Float, Sink, and Connect method will be most resource efficient because of the UCT's diving expertise. This method is more appropriate for gravity flow lines than for pressurized lines because of the difficulty in making pressure-tight joint connections underwater.

An aid to aligning and connecting pipe joints or strings on the seabed is the alignment frame. This provides bottom supported lifting capability which is necessary for proper alignment of pipe ends. These frames are more valuable for larger diameter pipe since their in-water weight is generally greater. It is recommended that a set of frames be designed, fabricated, and added to the equipment available for use. A set of frames is usually considered to be either two or four frames depending on size requirements. Figures 7-1 and 7-2 illustrate the subsea pipe alignment frame concept.

If small (6 to 8 inch) diameter lines must be installed in remote locations with rock or coral bottoms, consideration should be given to installing plastic floating lines similar to the Air Force fueling lines on Eniwetok Atoll. A steel cable provides stability and the line floats slightly off-bottom (See Pipeline Installation Reference No. 71). Installation is by a modified pull method with onshore pipe fabrication.

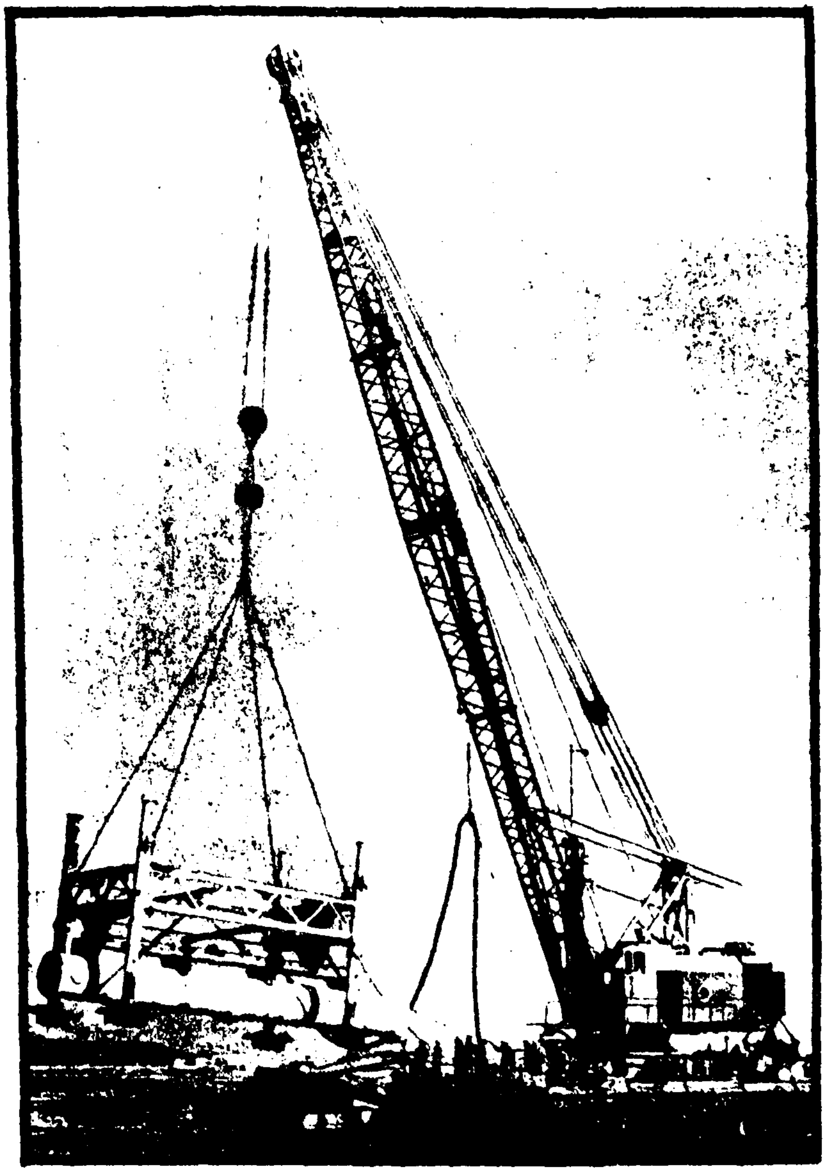

FIGURE 7-1

PIPE HANDLING FRAME ENTERING WATER *

* FROM: WESTERN CONSTRUCTION, VOL. 48, NO. 5, MAY 1973.

DRAWN BY J. DENTON	APPROVED: J. P. S.
DATE: FEB. 10, 1981	SCALE: NONE
DMJM	8413-01-01

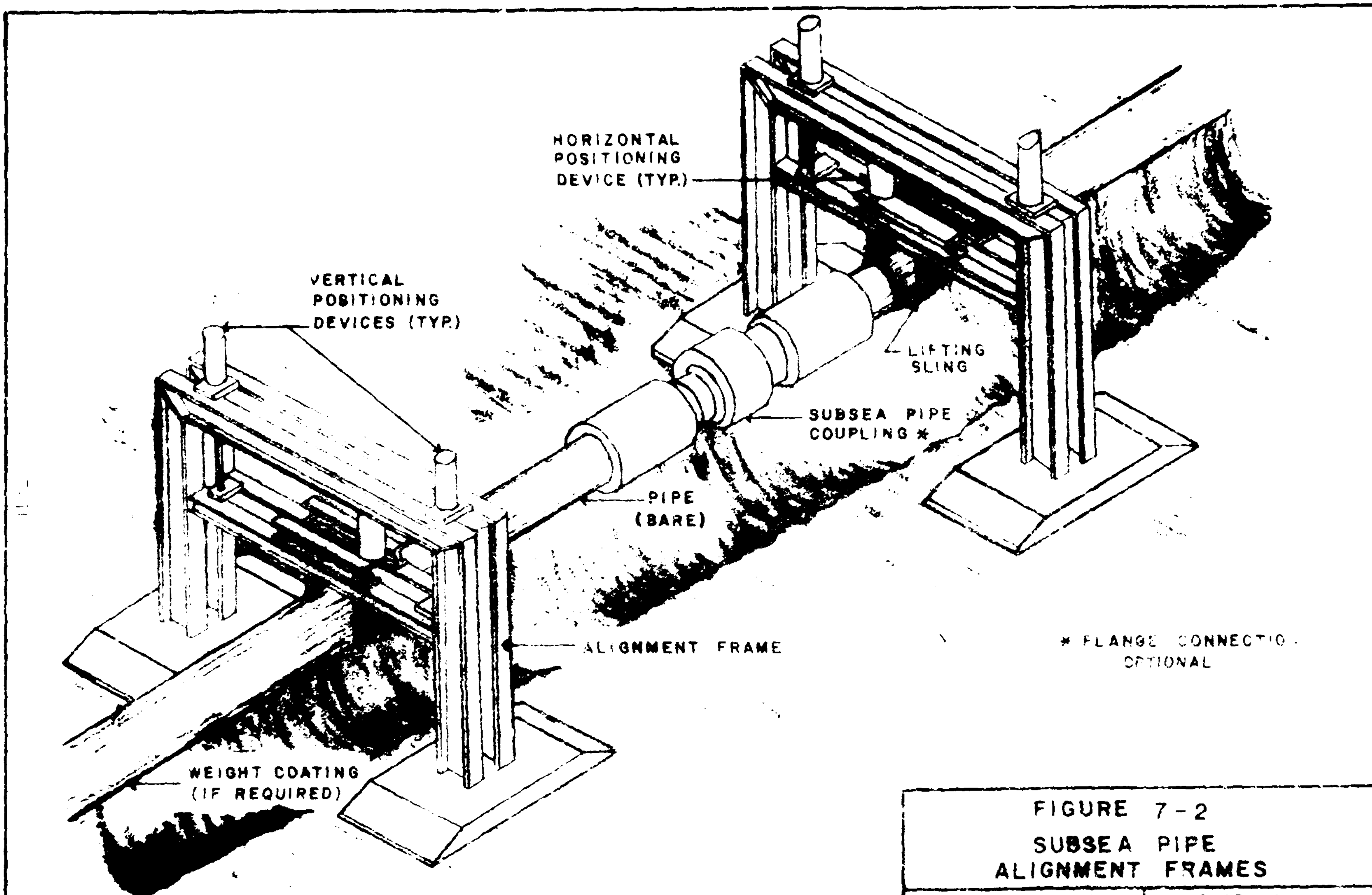

FIGURE 7-2
SUBSEA PIPE ALIGNMENT FRAMES

DRAWN BY: M. RICH	APPROVED: B.W.M.
DATE: MARCH 3, 1981	SCALE: NONE
DMJM	8413-01-01

Additional capabilities which should be considered include adding pipeline welders to the personnel complement, adding Flexifloat units or equivalent to the Tables of Allowance, and adding reel system laying capability for smaller lines. Pipeline welders enable the use of steel pipelines without employing outside services. Flexifloats coupled with a reel system will allow the UCT/NMCB to undertake a wide variety of nearshore pipeline projects.

Future projects which have no onshore work space could be installed from a Flexifloat center-slot lay barge as shown in Appendix G. If work space is available onshore the Flexifloat units could be assembled into a pull barge.

A study should be undertaken to define the flexible pipe requirements of the UCT/NMCB and potential size ranges. Simplex has done substantial work in the area of size increases but the work needs to be studied and modified for the UCT/NMCB application. Once the flexible pipe characteristics have been defined the reel design may begin. Initial efforts should concentrate on a maximum flexible pipe diameter of 8 inches. Reel design should be compatible with the Flexifloat concept.

Using the above recommendations future nearshore pipelines could be installed by the method most appropriate for the site conditions, pipe size, and pipe materials.

NOTES TO TABLES

(TABLES 7.2, 7.3, 7.4)

NOTES:

1. LIMITING SITE CONDITIONS are the work site conditions which would generally preclude the use of a method.

2. PIPE DIAMETER LIMITS showing 24 inches as the upper limit indicate study limits and not necessarily upper limits of the method or pipe availability.

3. OFFSITE LOGISTIC SUPPORT means support which would not normally be available at an onshore construction site where the pipe comes to shore. Pipe and equipment delivery to the onshore site is assumed for all methods.

4. OPERATIONAL LIFE is the expected operational life of the installed pipeline assuming no man-made damage. LOW is less than 15 years, MODERATE is about 15 years, HIGH is much longer than 15 years.

5. PREDICTION RISK is the level of risk associated with the prediction of the resources required for project completion. The level of prediction risk is directly proportional to the unknowns or nonquantifiable elements associated with using a given construction method.

6. EXPERIENCED CREWS mean personnel that are experienced in operating the equipment, tugs, winches, or other specialized equipment.

7. BARGES are assumed to be equipped with both a mooring system and lifting capacity, such as a crane.

CHAPTER 8

NEW CONCEPTS

8.0 GENERAL

New concepts are defined as those methods which have not been proven by field experience. There are many new concepts which are noted in the references. Others listed in this chapter came from previous studies and from consultation with DMJM's experienced in-house staff. Some of the concepts are not actually new but have simply never been tested. Some concepts are not entirely different or new, but they differ in one particular element (such as the connection technique). Others simply put existing technology together in a new or innovative manner.

Subsequent paragraphs identify the new concepts, analyze them for potential, and choose the most practical for further consideration.

8.1 NEW CONCEPTS

Following is a list of new concepts identified during the study. Numerous other ideas have been reviewed, but are not listed here because they were either very impractical or were very similar to the ones listed.

a) Telescoping pipe, where one joint fits inside another, floated into place, sunk, extended to full length, and connected to the next pipe.
b) "Barge Pipe" - floating, hollow structures which can be floated and joined together onsite and sunk to form a pipeline.
c) Mechanized, underwater crawler which can traverse the seafloor and pull a pipeline into place.
d) Mechanized, underwater laying and trenching machine which can trench, lay, and backfill a pipeline on the seabed.
e) Use of small submarine tow vessels, operated by divers, to tow buoyant pipe strings to the site, align, and sink on route.
f) Steel pipe joints assembled onshore with Cryofit Subsea or Betalloy couplings and installed by a pull method via a launchway. The new concept is the coupling.
g) Coil pipe in figure eight shape. Pipe would exit from the end.
h) Coil pipe in huge toroidal shape, hold together with adhesive, transport to site, and pull from the bottom of coil.
i) Modification to conventional reel method:

    1. Simultaneous lay, bury, and backfill concept.
    2. Equip reel with wide rims to spread bearing load and roll along seabed by gravity or tow.
    3. Mount reel on LCM and lay both offshore and onshore in one continuous operation.
    4. Install reel in a conventional ship.

5. Modify pipe material to reduce reel size.

j) Floating or semi-submerged reels:

1. Entire barge is semi-submerged reel with controls, personnel and required equipment in core of reel.
2. Floating reel is suspended between hulls of a catamaran or a catamaran submarine.
3. Large floating horizontal reels operated by thrusters.

k) Unconventional reel concepts:

1. Equip surface or floating reel with traveling threader device.
2. Reel designed to unroll or lay out pipe from the center (like rope coil).

l) Fiberglass reinforced epoxy pipe manufactured continuously and laid from the same vessel. The FRP would be made and cured on a spinning or "flying" mandrel in a continuous process. This concept has been developed, although it has not been field proven.

8.2 ANALYSIS OF NEW CONCEPTS

Few of the concepts listed in Section 8.1 hold promise of significant increases in resource efficiency over the state-of-the-art methods. Most would improve one or two elements of the installation but the overall effect for short, relatively small, nearshore pipeline projects would not be substantial. This, coupled with the research and development being performed by private industry, indicates that development of an entirely new method would not be cost effective. However, there are some elements which should be given further consideration. These include:

a) Develop simplified connectors especially for steel pipe.
b) Develop a multipurpose concept which would combine both laying and stabilization.
c) Modify reel concept and reel design for use with existing UCT/NMCB technology and vessels.

The most promising new couplings identified were the Cryofit Subsea and Betalloy. Only small diameter (less than 4 inch) couplings have been used to date. Additional required research would include expanding the technology to larger pipe sizes and developing a joint geometry which would withstand axial tension forces developed during a pull method of installation. If such couplings could be developed, steel and other rigid pipes could be joined together by personnel with minimum skills.

A multipurpose concept which holds promise is described as an "Anchor-Sled System". It is a variation of the off-bottom pull method but uses sleds or runners to hold the pipeline off-bottom. Once the pipeline is in place these sleds can be flooded, grout filled, or otherwise anchored to provide stability for the line. Figure 8-1 show a typical anchor-sled configuration. Tandem sleds connected to each other can be designed to withstand the pulling force. If plastic pipe is used with the concept it is probable that each set of sled supports would have to be linked together to carry the axial loads. Such a system could be utilized by the UCT/NMCB without substantial additional technology.

Another slight modification of this multi-purpose concept is to substitute rolling spheres, such as those described in Reference No. 21, or other buoyant, large bearing area shapes for the sleds. Again these could become anchors after installation (see Figure 6-6).

Reel concepts are the most viable methods for potential increases in on-site resource efficiency. It is possible to have a compact self-contained reel system which could be air-shipped to a construction site and installed with a minimum of on-site resources. Some of the elements which should be included in further evaluation are:

a) Develop skid-mounted unit which can be placed on the deck of a barge or ship of opportunity, or onshore.
b) Develop floating or semi-submerged unit which can be attached to standard Navy vessels (Seacon) or other vessels of opportunity and towed along the pipeline route.
c) Develop vertical reel unit designed to roll along the pipeline route on its rims as the pipe is unreeled. Such a unit would lay the onshore and offshore segments as it rolled down the slope.

Further study and analysis is required to isolate the concepts which have the greatest potential for maximum utilization by the UCT/NMCB.

Areas of the reel concept which require research and development are:

a) Selection of a pipe material which will handle the design pressure and fluids, yet have a small enough bending radius to allow the reel diameter to be reduced to a minimum. Some of the presently designed flexible pipes and hoses may fit the need but are not available in a full range of diameters.
b) Integration of a tensioning capability into the reel design.
c) Reduction of the size of the overall reel package to allow for practical shipment.

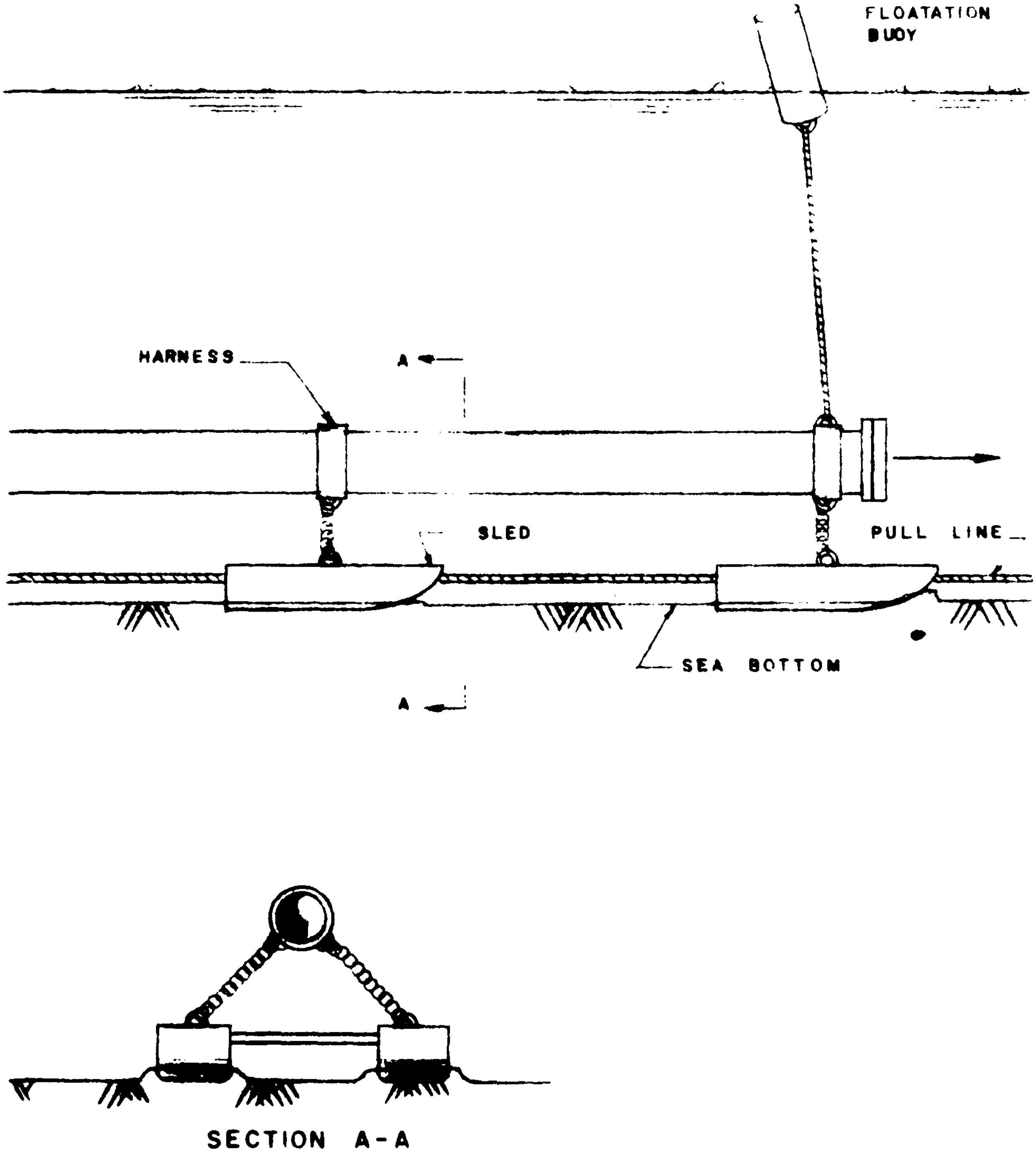

FIGURE 8-1 ANCHOR-SLED CONCEPT	
DRAWN BY: J. STEARNS	APPROVED: J.P.S.
DATE: FEB. 9, 1981	SCALE: NONE
DMJM	8413-01-01

A P P E N D I X   A

PIPELINE INSTALLATION REFERENCES

APPENDIX A

PIPELINE INSTALLATION REFERENCES

A.0 GENERAL

The nearshore pipeline installation method classifications including their subdivisions are numerically keyed to the accompanying list entitled REFERENCES.

The REFERENCES list is a bibliography of the articles used for the literature search on submarine pipeline installations. By using the numbers listed for each installation method specific articles regarding a given installation method can be obtained.

A.1 INSTALLATION CLASSIFICATION

1. ONSHORE ASSEMBLY, SURFACE CONNECTION:

A. Pull Method:

9	33	73	97	135	171	207	255
12	38	74	108	144	174	209	258
13	62	77	109	154	182	218	267
14	64	82	117	160	184	229	271
21	70	90	119	162	205	231	
25	72	93	120	168	206	254	

B. Reel Method:

9	81	122	128	144	167	250	259
28	107	127					

C. Float, Connect, and Sink:

9	51	109	144	192	213	218	268
31	70	120	174				

D. Directional Drilling:

117

II. ONSHORE ASSEMBLY, SUBSURFACE CONNECTION

A. Float, Sink, and Connect:

34 159

B. Bottom Tow and Connect:

2 8 30 41 215 248

III. OFFSHORE ASSEMBLY, SURFACE CONNECTION

A. Lay Barge:

9	73	86	94	117	149	182	214
23	75	87	99	120	155	189	216
27	79	88	100	133	156	191	218
29	81	92	105	142	174	192	260
70	84	93	114	144	181	212	

IV. OFFSHORE ASSEMBLY, SUBSURFACE CONNECTION

A. Trestle Method:

257

B. Jack-Up Platform:

121 172

A.2 OTHER TOPICS

Two other topics which are relevent to pipeline installations are:

a) Anchoring/Stabilization
b) Trenching

These two topics are keyed to the articles listed in REFERENCES, also. These numbers reference specific articles on these topics.

a) Anchoring/Stabilization

58	112	265	266

b) Trenching

9	66	70	218	268	271	272
11	68	179	253			

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APPENDIX B

NEARSHORE ZONE - DISTANCE FROM SHORELINE

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NEARSHORE ZONE - DISTANCE FROM SHORELINE

A distance of two miles from shore is considered the nearshore zone. Two miles was selected by the CEL and DMJM as appropriate for the scope of this study.

The definition of "nearshore" is "the zone extending seaward from the shoreline well beyond the breaker zone and where currents affected by the bottom exist." This zone is actually dependent on location and environmental conditions and will change from time to time and place to place. Therefore, one way to confirm this maximum pipeline distance is to evaluate the coastlines under study with respect to the following criteria:

a) The distance should include the nearshore zone in all cases.
b) For most cases, the maximum depth should be less than 130 feet.

The coastline evaluation was performed using navigation charts and topography maps from DMJM files. The area was divided into six sections as follows:

a) The northern U.S. Atlantic Coast from Cape Hatteras northward.
b) The southern U.S. Atlantic Coast from Cape Hatteras southward.
c) The entire U.S. Gulf of Mexico Coast and western Florida Keys.
d) The northern U.S. Pacific Coast from Cape Mendocino northward.
e) The southern U.S. Pacific Coast form Cape Mendocino southward.
f) All coastlines of the Hawaiian Islands.

Contours of distance from shore were constructed and correlated with the available bathymetry information.

The northern and southern U.S. Atlantic Coasts and U.S. Gulf of Mexico Coast are characterized primarily by small slopes near the shoreline. The 130 foot depth contour extends far beyond ten miles from shore in most cases. Exceptions to this are the Mississippi River Delta, the Florida Keys and South Florida Coast, the approach to New York Harbor, and the area north of Cape Cod. Along the Maine Coast, there are points where deep waters come close to shore; however, due to the unevenness of the shore, they are hard to pinpoint. On the other extreme, the 130 foot contour is as far as 75 miles offshore from the mouth of the Sabine River at the Texas-Louisiana border. Slopes are gradual and smooth in general.

The U.S. Pacific and Hawaiian Coasts are almost totally opposite in bathymetric makeup. The 130 foot contour is within five miles from shore at all points, except near major bays and rivers, such as San Francisco Bay and the mouth of the Columbia River. The contour averages one to two miles from shore along the Pacific Coast. Based on scattered profile data available to DMJM, the closest to shore that the contour reaches is about 1,800 feet. Profiles show uneven slopes in many cases. Hawaii's coastline is similar to the U.S. Pacific Coast.

Based on our review of coastline topography, two miles is confirmed as a reasonable distance for the pipeline study. There are only a few places on the Pacific Coast and Hawaii where depths will exceed 130 feet at 2 miles from shore. In these places, deployment vehicles should be able to approach closer to shore since the outward distance of nearshore effect is smaller. Only in unusual cases will the offshore terminal point be affected by nearshore wave and current patterns or be in water depths exceeding 130 feet.

APPENDIX C

SITE SCENARIOS

APPENDIX C

SITE SCENARIOS

Development of the various characteristics of typical construction sites in the areas of consideration must be performed as an initial step in the comparison process between different pipeline installation techniques. Categories for sites will be defined by two parameters, bottom materials constitution and bottom slope. Again, information concerning these aspects have been obtained from existing localized charts of the east and west United States coastlines and the nearshore zones of the Hawaiian Islands.

Sloping sandy beaches exist along most of the east coast south of Cape Cod. Barrier islands lie in many areas, and sandbars exist close to the shoreline. Nearshore sediments are primarily sands, with silty sands around the mouths of most estuaries and bays. Typical bottom slopes near the coast are 1:1000 between Cape Hatteras and Cape Kennedy, 1:800 between Cape Cod and Cape Hatteras, and 1:600 south of Cape Kennedy. Coastlines generally front marshes or hard-packed sandy developed lands. Conditions are similar along the United States Gulf of Mexico coastline, with nearshore bottom slopes averaging 1:600 east of the Mississippi River and 1:1000 west of the River. In the river delta, sandy and clayey silts are found with a typical nearshore slope 1:200.

Coastal characteristics change north of Cape Cod. Rock outcrops occur with increasing frequency to the north along both the shorelines and inland sections. Most of the coastline north of Portland, Maine is comprised of jagged rocky cliffs with only occasional pocket beaches. Bottom slopes are quite steep, with slopes of 1:70 being typical and locally steeper slopes frequently found. The few beaches that exist are made up of sand and cobbles. The rocks and cliffs are less severe to the south of Portland.

The west coast of the United States is similar in many ways to the Atlantic coast north of Cape Cod. Most of the shorelines are rocky with occasional steep, sandy beaches. Inland, volcanic and quarternary rock predominate in undeveloped sections. Bottom sediments are mainly coarse sands consisting of detrital quartz and feldspar, with gravel and cobbles in places. Muds and silty sands can be found near river mouths. Bottom slopes along the California coast average about 1:50 with an extreme of 1:12. Along the Oregon and Washington coasts, bottom slopes are less severe, with typical ratios of 1:100 and an extreme of 1:35. Slopes range down to 1:10 north of Washington into the Strait of Juan de Fuca. Hawaii is similarly characterized by steep sand or gravel beaches and nearshore areas. Sediments are genrally coral sands. Bare areas or coral bedrock are common. Bottom slopes of 1:20 to 1:100 are typical.

Two general installation scenarios can be established from the coastline information. One scenario consists of deployment across a sandy beach with a bottom and shore slope of 1:750 that is fairly constant except for sandbars close to the shoreline. The nearshore bottom will be comprised of silty sands, with small areas of gravel and/or cobbles. Inshore, marshes or sand dunes will exist. These conditions are typical for the east coast south of Cape Cod. The second scenario takes into account conditions similar to those

found along the west coast and the east coast north of Cape Cod. Installation will be achieved across a small sand or gravel beach bordered by rock cliffs or boulders. The nearshore bottom will be comprised of coarse sands with areas of gravel, cobbles, and bedrock. The bottom slope will be 1:75 and will vary along the route. Sketches of these two scenarios are included as Figures C-1 and C-2.

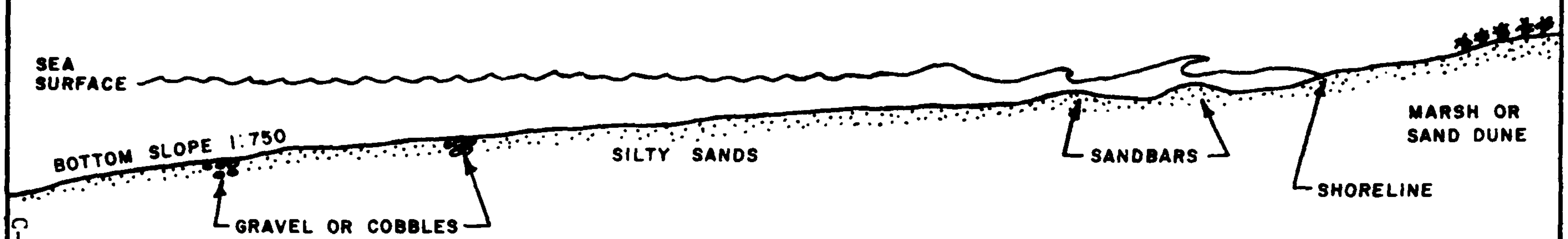

FIGURE C-1 CONSTRUCTION SITE SCENARIO ONE	
DRAWN BY: J. DENTON	APPROVED: B.W.M.
DATE: JAN. 19, 1981	SCALE: NONE
DMJM	8413-01-01

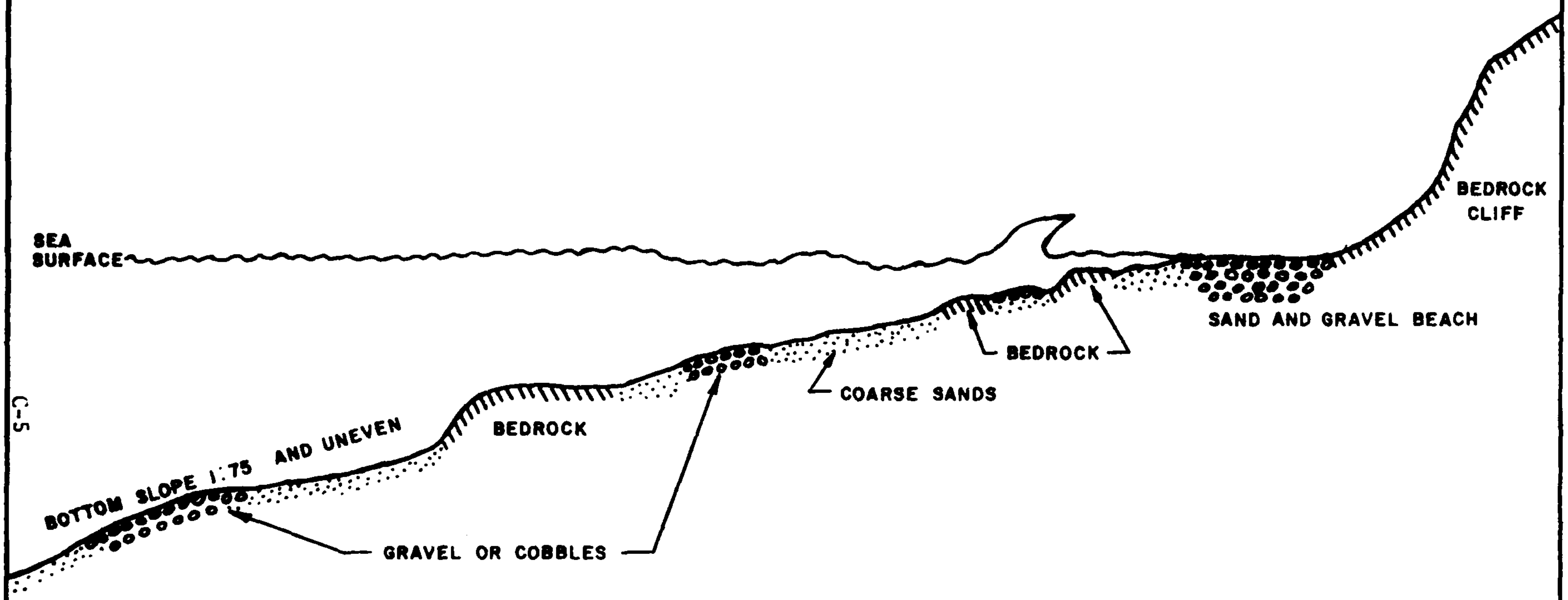

FIGURE C-2
CONSTRUCTION SITE
SCENARIO TWO

DRAWN BY: J. DENTON	APPROVED: B.W.M.
DATE: JAN. 19, 1981	SCALE: NONE
DMJM	8413-01-01

APPENDIX D

ENVIRONMENTAL EFFECTS

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ENVIRONMENTAL EFFECTS

Any marine pipeline must ~~be able~~ to withstand the effects of the most severe oceanographic ~~conditions~~ expected during its design life. Characteristics of ~~these most~~ severe conditions must be recognized prior to determination of the method or methods best suited for stabilizing the pipeline. In addition, the pipeline installation method and procedure must be selected in order to withstand potential oceanographic conditions during the construction period. Establishment of these forces and features usually requires a determination of the worst expected conditions during the pipeline design life. A diagram of the various considerations is included as Figure D-1. In this case, upper limits of environmental conditions will be established as a basis for feasibility analysis. These limits will include nearly all conditions that would be expected during operations.

Currents and waves will have the primary effects on pipeline deployment and in-place stability. There are several types of ocean currents that may act together to produce currents at a single site. Wind-driven currents are generated by winds blowing over the water. These currents are fastest near the surface and slow exponentially with increaing depth. Tidal currents are created from the gravitational attractions between the sun, moon, and earth. Such currents are cyclical and can be predicted using site-specific hydrographic models. Density (or turbidity) currents occur when two water masses of differing characteristics meet; the heavier water mass flows downward along the bottom while the lighter water mass replaces the heavier mass. Hydrographic currents are found in and near the mouths of rivers and are dependent upon the amount of flow coming through or from the river.

In nearshore zones, longshore currents can develop as a result of wave interaction with the shoreline. When waves approach the shoreline at an angle, bottom-induced friction causes wave refraction to occur. The wave direction becomes more parallel with the shoreline; however, in many cases, the process is not completed before wave breakage. As a result, the waves break on an outside sandbar or on the beach at an angle. There is then a resultant flow of water along the shoreline from the beach to the point where the waves break. Longshore current velocities are mainly dependent upon the angle of wave attack and wind speed and direction. A typical longshore current velocity is one foot per second (0.6 knots) if simply wave induced; however, speeds up to 5.5 feet per second (3.3 knots) may develop with the aid of the wind.

Mean current speeds are less than one knot for at least 70 percent of the time in the area of consideration except along both Florida coasts and the Georgia coast, where currents of less than one knot occur as little as 15 percent of the time in places. This is caused by the Gulf Stream and related system and is anomalous in considering all shoreline areas. Thus, one knot has been established as the upper limit for incidental currents on the pipeline, except in the nearshore zone, where 1.6 knots has been established as the upper limit to include longshore current potential. It should be noted that currents are site-specific and may vary substantially between two nearby points.

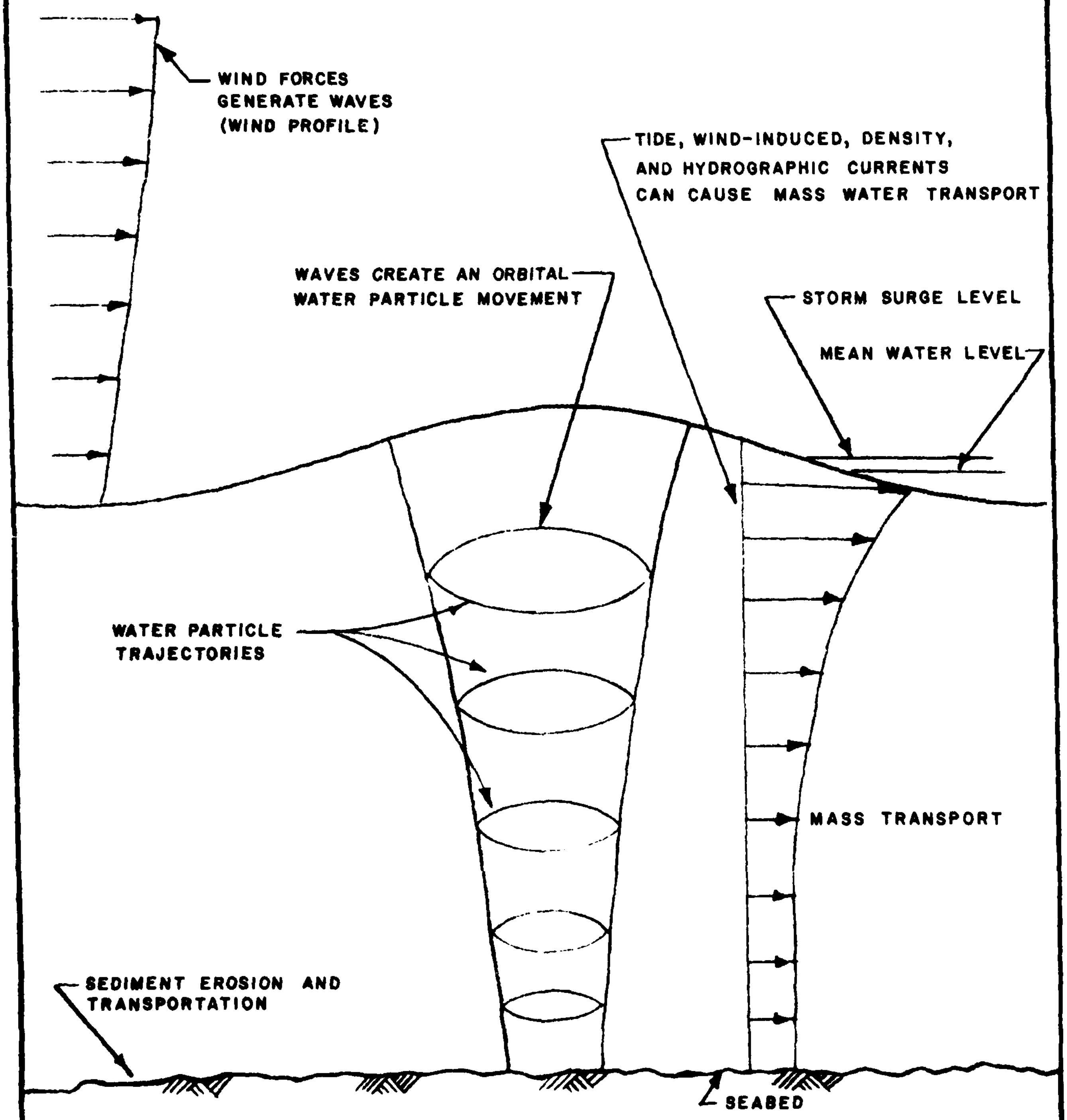


FIGURE D-1
OCEANOGRAPHIC CONSIDERATIONS
(TYPICAL)

DRAWN BY: M. RICH	APPROVED: B.W.M.
DATE: APRIL 27, 1981	SCALE: NONE
DMJM	8413-01-01

Added to the design currents are particle velocities and accelerations produced by waves. Waves are generated primarily by winds and are classified into two categories: 1) wind waves (or seas), a product of local winds, and 2) swell, a product of distant winds. Waves are characteristized by their height (or amplitude); their period, which is the time that elapses between two wave passages; and the water depth below their surface track. Various wave components generated near or far from the pipeline site can be analyzed to predict their strength at any location.

Wave heights and periods are usually functions of wind speeds from a given direction and are dependent on two other parameters: 1) the duration, which is the length of time that the wind blows from a specific direction and at or above a set speed, and 2) the fetch, which is the distance over water which wave-producing winds can operate. Nomographs exist which may be used to estimate the significant and extreme wave heights and periods for a certain location given wind speed, duration, and fetch.

The height and period of a wave may be altered by three topographical considerations. The first, shoaling, takes into account the fact that waves deform and grow in height when water depth is shallow and decreasing. Secondly, refraction causes waves to change direction due to frictional effects on the sea floor. Finally, diffraction produces partially or totally reflected wave energy from natural or man-made barriers. One or more of these features may act to increase the expected size and strength of the approaching wave.

Breaking waves at or near the shoreline form the area generally known as the "surf zone". Breaking waves are a function of water depth versus wave height. As waves approach the shoreline, their height above the still water level increases, and both wavelength and velocity decrease. The wave breaks when the theoretical ratio of water depth to wave height becomes equal to 1.333. Breaking waves are classified into four categories (spilling, plunging, collapsing, or surging), depending upon the kinetic energy in the wave and the nearshore bottom slope.

Since coastline bathmetry changes with geographic location, no set distance from shore can precisely be stated for which waves or a given height will break. Generally, the location of the outermost sandbar is considered the outer edge of the surf zone. This may change from season to season, i.e. winter waves generally create sandbars further offshore than summer waves due to differences in wave energy.

Many wave climates exist along the east and west coasts of the United States. Overall, waves of five feet or greater occur 30 to 40 percent of the time along most United States coastal areas. Occurrence percentages are generally higher in winter and higher with increasing latitude. Five feet has been selected as an upper limit for significant wave height for pipeline deployment and installation operations since waves of less than five feet in height are experienced most of the time. The same upper limit is recommended for surf zone considerations, since the shallow water waves will not increase in

overall height, even though they will appear higher above the still water level. Breaking waves will have their primary force components directed inward (to shore); therefore, lateral wave forces on a pipeline perpendicular to the shoreline will be less than the wave forces along the pipe.

Earthquakes and tsunamis can affect all coastlines, although they are most predominant along the west coast and Hawaii. Their frequency of occurrence; however, is small enough so that they would not be expected to affect the type of operations being considered in this study. Therefore, no additional consideration has been given to these phenomena with respect to site factors.

APPENDIX E

UCT/NMCB MANPOWER

APPENDIX E

UCT/NMCB MANPOWER

The following list of construction and marine personnel was developed from actual jobs performed by Navy personnel. It is a generalized listing including job titles and functions. The actual number of personnel available is unknown, and the number of specific personnel required for a given installation method is not specified. This would be a function of specific project requirements and time factors. Therefore, no quantities are indicated. It is assumed that an adequate supply of personnel, complete with support personnel required, will be available to satisfactorily complete a pipeline installation using a specified construction method.

ITEM NO.	QNTY.	JOB TITLE	FUNCTION	REMARKS
1	-	Beachmaster	In Charge of All Operations	It is assumed for a given construction method that adequate quantity of personnel are available to satisfactorily complete the installation.
2	-	Inspector	Quality Control Supervisor	(Same as above)
3	-	Engineer	Provide Technical Guidance	(Same as above)
4	-	Observer	Monitor Visual and Radio Communications	(Same as above)
5	-	Surveyor	Establish Position Control System	(Same as above)
6	-	Welder	Welding of Steel Pipe if Required	(Same as above)
7	-	Welder Helper	Assist Welder if Required	(Same as above)
8	-	Winch Operator	Operate Pull Winch	(Same as above)
9	-	Ditching Machine Operator	Operate Ditching Machine	(Same as above)
10	-	Road Grader Operator	Operate Road Grader	(Same as above)
11	-	Crane Operator	Operate Cranes	(Same as above)
12	-	Dozer Operator	Operate Dozer	(Same as above)
13	-	Loader Operator	Operate Loader	(Same as above)
14	-	Excavator Operator	Operate Multipurpose Excavator	(Same as above)

ITEM NO.	QNTY.	JOB TITLE	FUNCTION	REMARKS
15	-	Heavy Equipment Mechanic	Repair and Maintain Heavy Equipment	It is assumed for a given construction method that adequate quantity of personnel are available to satisfactorily complete the installation.
16	-	General Mechanic	Repair and Maintain Other Equipment	(Same as above)
17	-	Labor	General Labor Pool	(Same as above)
18	-	Truck Driver	Drive Different Truck Types	(Same as above)
19	-	CPO	Boat Operations Supervisor	(Same as above)
20	-	LCM/LCU Boat Chief	LCM/LCU Skipper	(Same as above)
21	-	LCM/LCU Crew	Crew Members of LCM/LCU	(Same as above)
22	-	LARC Boat Chief	LARC Skipper	(Same as above)
23	-	LARC Crew	Crew Members of LARC	(Same as above)
24	-	Diving Supervisor	Supervisor of Diving Operations	(Same as above)
25	-	Diver	Scuba and Hat Divers	(Same as above)
26	-	Tender	Diving Operation Tenders	(Same as above)
27	-	SEACON Crew	SEACON Operations and Support	(Same as above)

APPENDIX F

UCT/NMCB EQUIPMENT

APPENDIX F

UCT/NMCB EQUIPMENT

The following list of construction and marine equipment was compiled from a review of the Tables of Allowance of support equipment for an Underwater Construction Team and a Navy Mobile Construction Battalion. Additional information was obtained via communications with Civil Engineering Laboratory personnel. Diving equipment was assumed based on minimum requirements.

Equipment listed in supplementary information and reports was not used as it could not be established whether or not this equipment is actually available for UCT/NMCB use. Also, there was reason to suspect that some of the equipment listed in the reports may be a duplication of equipment listed in the Tables of Allowance. Thus, equipment count duplication was avoided which maintained the guideline of a conservative approach.

ITEM NO.	QNTY.	DESIGNATION	DESCRIPTION	REMARKS
1	3	Air Compressor	365 CFM with Hose Accessories	May be used for filling pipeline floaters and dewatering pipeline.
2	1	Air Compressor	250 CFM with Hose Accessories	May be used for pipeline floaters and dewatering pipeline.
3	2	Air Compressor	125 CFM with Hose Accessories	May be used for pipeline floaters and dewatering pipeline.
4	10	Air Hose Kits	Miscellaneous Hose Kits	May be used as required for dewatering and filling floaters.
5	1	Power Winch	2 Drum, Variable Speed, 150 HP	With 33,000# pull should be investigated for use as pull winch for small and medium diameter lines of short or medium length. Also use as holdback winch.
6	1	Generator	100 K/W A/C Skid Mounted	Possible onshore and offshore power source.
7	3	Generator	30 K/W A/C Skid Mounted	Possible onshore and offshore power source.
8	2	Generator	15 K/W A/C Skid Mounted	Possible onshore and offshore power source.
9	1	Generator	5 K/W A/C Skid Mounted	Possible onshore and offshore power source.
10	4	400 AMP Arc Welder	Generator Type, Trailer Mounted	Steel pipe assembly for reel or onshore pull or Lay Barge methods.
11	4	M/V Floodlight Set	Two-1000 Watt, Trailer Mounted	Night operations lighting.
12	2	Concrete Mixer	16 Cu.Ft. Trailer Mounted	Use for pouring deadman anchors.
13	1	Ditching Machine	Wheel Mounted	Trenching capability at shoreline.

ITEM NO.	QNTY.	DESIGNATION	DESCRIPTION	REMARKS
14	1	Ditching Machine	Crawler, Ladder Type, 7 ft. D, 8'-24" W.	Trenching capability at shoreline.
15	4	Road Grader	6 x 4 Open Canopy	Onshore pull staging area preparation.
16	1	Crawler Crane	12-½ Ton with Clam, Dragline, Pile Driver	Shore approach excavation, Sheet Pile Driving.
17	1	Crawler Crane	Block; 40 Ton	Reel Lift; Pipe Handling; Equipment Lift.
18	1	Wheeled Crane	30 Ton; Revolve; Telesc. Boom; Outriggers	Reel Lift; Pipe Handling; Equipment Lift.
19	1	Wheeled Crane	12-½ Ton; Revolve; Telesc. Boom; Outriggers	Pipe Handling; Equipment Lifting.
20	1	Truck Mounted Crane	35 Ton; Block & Pile Lead Adapter	Reel Lift; Pipe and Equipment Lifting; Sheet Pile Driver.
21	1	Truck Mounted Crane	25 Ton with Block	Pipe and Equipment Handling.
22	2	Crawler Dozer	160 HP; Rear Mounted Winch	Staging area preparation and Holdback for Pull method of pipelay.
23	1	Crawler Dozer	160 HP with 6" Hazard Hose Coupler	Staging area preparation and Holdback for Pull method of pipelay.
24	1	Crawler Dozer	160 HP with Ripper	Staging area preparation and Holdback for Pull method of pipelay.
25	1	Crawler Dozer	300 HP with Ripper	Staging area preparation and Holdback for Pull method of pipelay.
26	1	Crawler Dozer	300 HP; Rear Mounted Winch	Staging area preparation and Holdback for Pull method of pipelay.
27	3	Crawler Dozer	105 HP	Staging area preparation and Holdback for Pull method of pipelay.

ITEM NO.	QNTY.	DESIGNATION	DESCRIPTION	REMARKS
28	2	Crawler Loader	2-½ cu.yd. Bucket	Staging area preparation and Auxiliary Holdback for Pull Method.
29	1	Crawler Loader	2-½ cu.yd. Bucket; Rear-Mounted Hoe	Staging area preparation; Auxiliary Holdback for Pipe Pull and onshore trenching.
30	2	Wheeled Loader	2-½ cu.yd. with Forks, Hoe, Blade, Crane	Staging area preparation.
31	1	Wheeled Loader	2-½ cu.yd. with Forks and Coupler	Staging area preparation.
32	1	Multipurpose Excavator	6 x 6 Truck Mounted; Bucket and Ripper-tooth	Staging area preparation and onshore or shore approach trenching.
33	numerous	Various Transport Vehicle	Cargo, Utility, Wrecker, Tractor Trailer, Low Bed, Stake, Dump, Vehicles	Numerous vehicles of various types are available for equipment and personnel transport and servicing.
34	1	LARC 5	5 Tons Onshore Carrying Capacity; 19,000# Air Weight; 270 HP; 20,000# Onshore Pulling Capacity; 10' x 13' Usable Deck Space;	Low pulling capacity in water; Poor in-water stability; Aluminum construction. Useful for equipment and personnel transport; Could be used to pass messenger line. Not suitable for pull platform or reel barge. Pull point near top.
35	1	LCM 8	48 Tons Carrying Capacity;600 HP; 15' x 45'Usable Deck Space;	Should be investigated for possible use as a pull platform. Not large enough for large reel barge. Has 4 engines - twin screws.

ITEM NO.	QNTY.	DESIGNATION	DESCRIPTION	REMARKS
36	1	LCM 6	34 Tons Carrying Capacity; 385 HP; 11' x 37' Usable Deck Space	Should be investigated for possible use as a pull platform. Not large enough for reel barge concept. Has 2 engines - twin screws.
37	1	LCU 1610	60 Tons Carrying Capacity; 1000 HP; 22' x 112' Usable Deck Space	Used on past project as anchored work platform. Is 139' OA x 29' Beam. Has 4 engines - twin screws; Should be investigated for expanded use as a pull platform or reel barge concept.
38	1	LARC 15	15 Tons Carrying Capacity; 500* HP; 40,000#* Onshore Pulling Capacity; 20' x 25'; Usable Deck Space	Questionable pulling capacity in water; Questionable in-water stability; Has some potential as a work platform or pull platform that should be investigated. However, it may be useful only as equipment or personnel transport. Could also be used to pass messenger line. Much too small for reel barge.
39	1	Propelling Unit	295 HP Engine	Survey boat and Personnel boat potential.
40	Assume 2	Diving Hat and Hose		Use for cutting floaters for the lay barge method.
41	Assume 2	Scuba Equipment		Use for cutting floaters for the lay barge method.
42	Assume 2	Scuba Compressor		Use for cutting floaters for the lay barge method.

*ESTIMATED

ITEM NO.	QNTY.	DESIGNATION	DESCRIPTION	REMARKS
43	Assume 2	Chamber Compressor	With Volume Tank	Use for cutting floaters for the Lay barge method.
44	Assume 1	Hat Compressor	With Volume Tank	Use for cutting floaters for the lay barge method.
45	Assume 1	Decompression Chamber	One Man; Double Lock	Use for cutting floaters for the lay barge method.
46	Assume 1	Communications Box		Use for cutting floaters for the lay barge method.
47	Assume 1	SEACON	Sea Construction Platform, 135' x 40' Deck Space	Pipe laying platform or support vessel.

APPENDIX G

<u>FLEXIFLOAT SYSTEM</u> *

*From Flexifloat Systems Catalog, courtesy of Robishaw Engineering, Inc. Flexifloat is a registered trademark of Robishaw Engineering, Inc. Houston, Texas.

THE FLEXIFLOAT SYSTEM

FLEXIFLOATS are standardized, precision-built, watertight, welded steel buoyant units incorporating a high strength internal structure and external locking mechanism for interconnecting adjacent units into usable shapes having adequate buoyancy, strength, and stability characteristics for supporting all weights and types of mobile equipment used in operations involving floatation and bridging.

THE PORTABILITY SYSTEM -- Flexifloats, externally dimensioned for permissible overland transport with conventional trucks and trailers, have unit weights that can be easily handled by available job-site lifting equipment. Decks and bottoms are free of projections that obstruct stacking or sliding one unit over the other. Each unit has an integrated lifting clevis at its balance center and rope thimbles around the perimeter for launching, mooring, and assembly.

FLEXIFLOAT EQUIPMENT, consisting of standardized floatation structural units and multipurpose attachments and accessories, facilitate the design of assemblies of any shape required to effectively perform every floatation and bridging function involved in construction, exploration and development operations. All units of equipment are designed and dimensioned for ease of handling, freedom of transport, simplicity of assembly, and practical economic application by inexperienced personnel to both over-water and underwater applications at diverse locations.

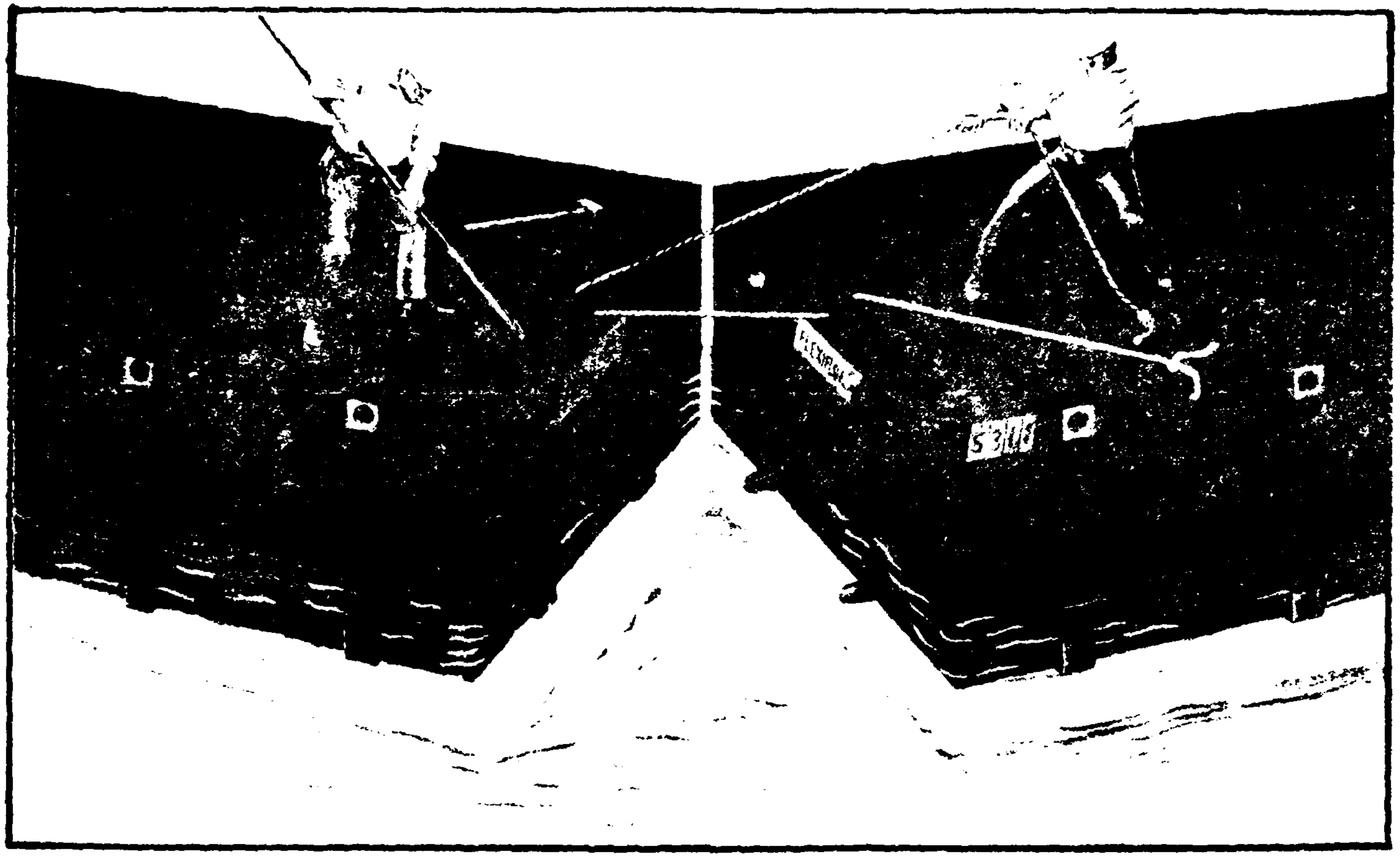
THE UNIT LOCKING SYSTEM

The high strength Flexifloat locking system is simple, quick, and positive. It is designed for on-deck operation while afloat by inexperienced personnel without special tools or loose components that may be lost or damaged in transit. Locking top and bottom is accomplished simultaneously with positive indication that both are engaged. The connection system has built-in features that prevents disengaging while under load and freezing in the engaged position due to stressing, corrosion, or marine deposition.

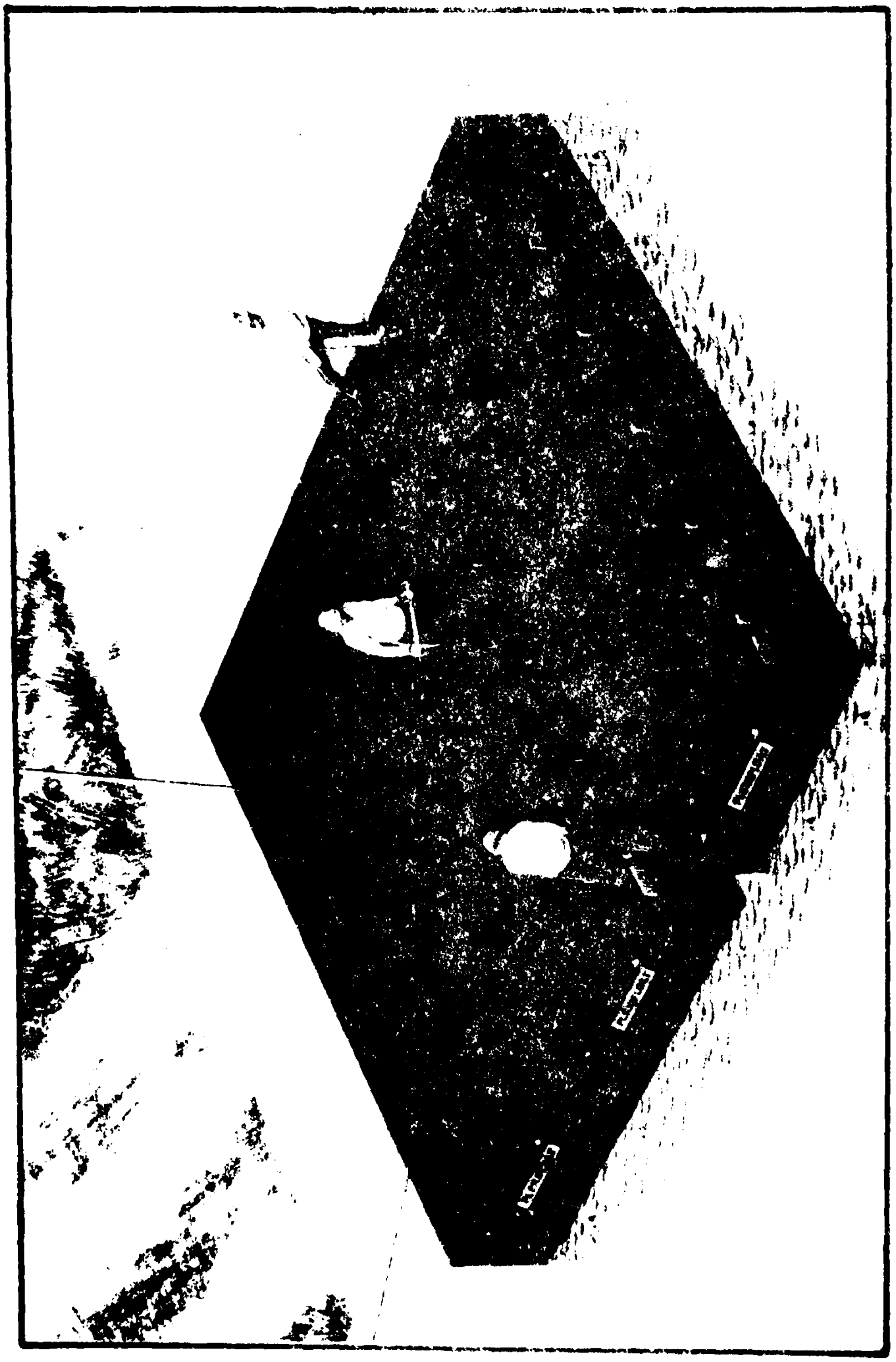
THE FLEXILOCK SYSTEM is divided into two Locking Units, one male and the other female. Each unit has an upper and lower connector. Matching male and female Locking Units are precision-spaced around the perimeter of the float on opposite sides and ends, and are connected to each other by interior transverse and longitudinal trusses of special design. Engaging and disengaging matching units on adjacent floats is accomplished with the Locking Bar which is an integral part of the female Locking Unit. The lock is opened when the bar is raised with a pry bar and remains open until the bar is driven down to engage and lock.

THE UNIT ASSEMBLY SYSTEM -- The design features coupled with precision spacing of the male and female Locking Units and close control of distortion during shop fabrication assures complete interchangeability of all units and ease of assembly under field conditions.

THE ASSEMBLY METHOD -- All floats within each model series have equal and uniform draft. Assembly of adjacent floats is accomplished by an inexperienced crew of three men or less in negligible time with no other tools other than a hammer, a pry bar, and short sections of rope. All mating female locks are opened with the pry bar, the floats are pulled into alignment with ropes threaded through thimbles on each float, the locks are mated until upper and lower faces are in near contact, and the Locking Bar is driven down with the hammer until seated. The Locking Bar performs a wedging action to pull the floats into final mating position.



THE UNIT LOCKING SYSTEM



BEACH LANDING ASSEMBLIES

For applications in ship-to-shore discharge operations Flexifloat Equipment may be transported on deck and arranged alongside into assemblies designed and dimensioned for effective transport of heavy construction, exploration, and development equipment and materials. Ramps are provided with hinges and hydraulic actuating system for convenience in propulsion and beach unloading.

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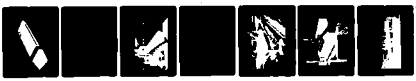

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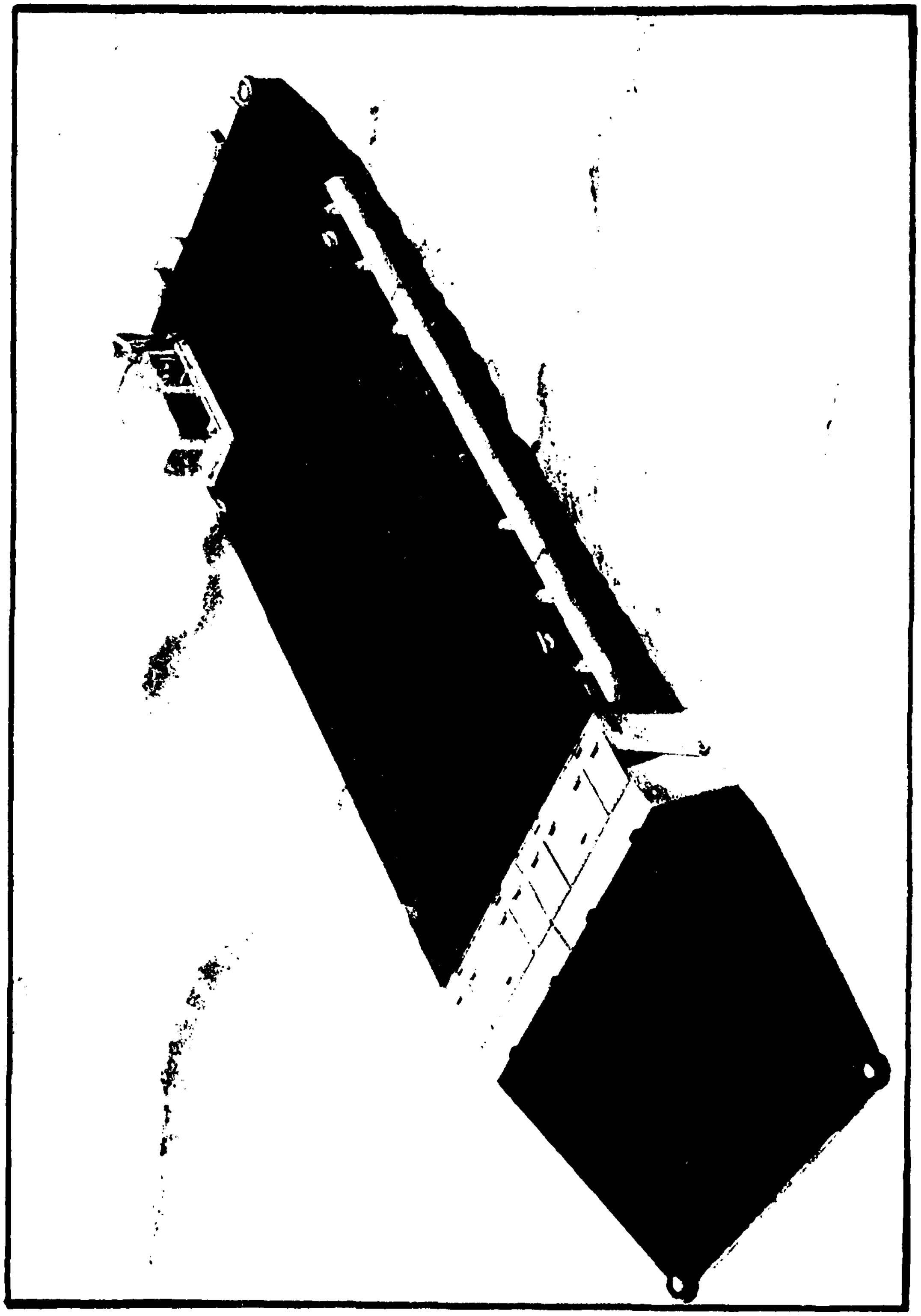


BEACH LANDING ASSEMBLY

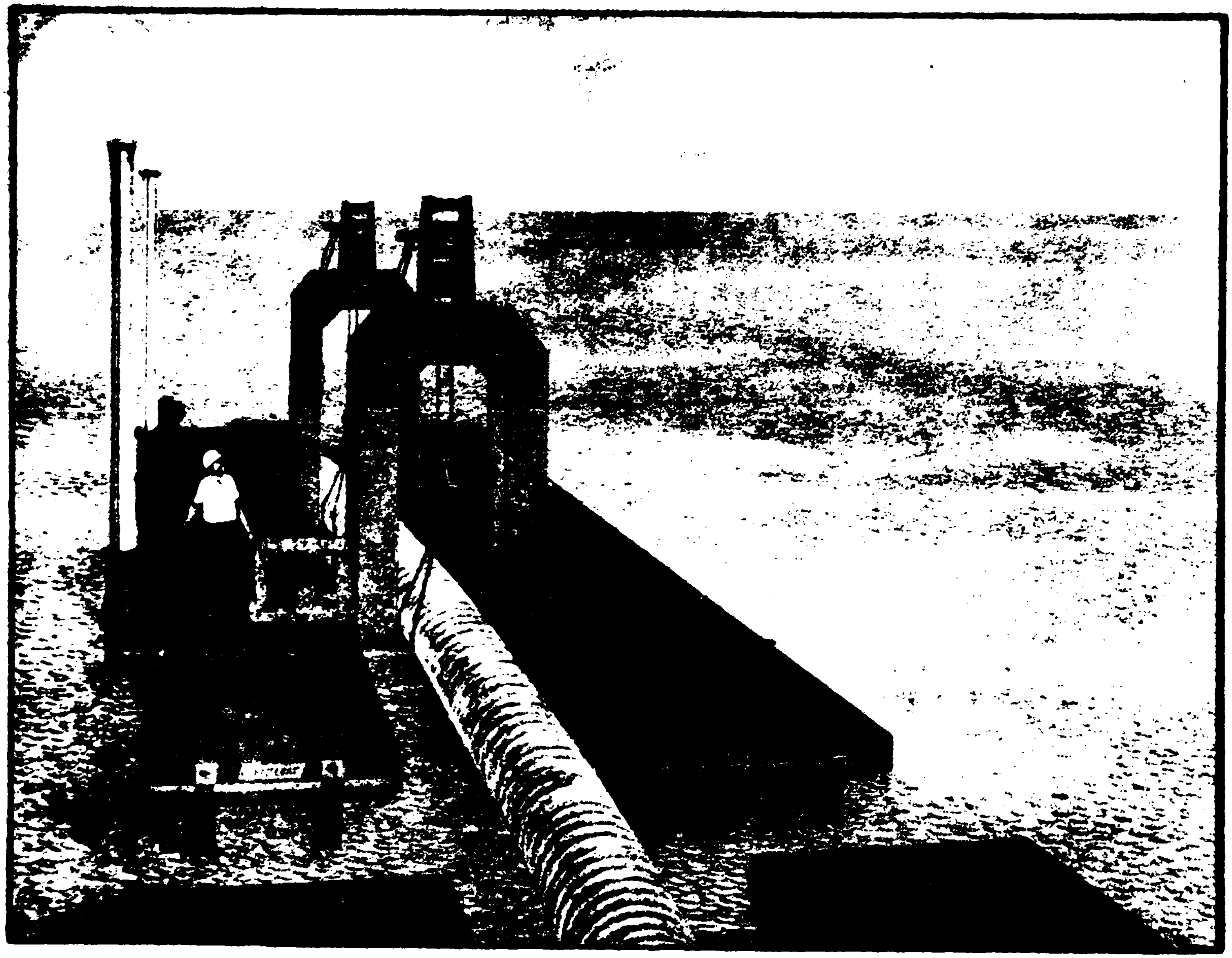
PIPELINE CONSTRUCTION ASSEMBLIES

Flexifloat Systems had its origin and its greatest development in the pipeline construction field. The unit system of floats and attachments filled the need for equipment that could be readily adaptable to the many different problems encountered in cross country underground line construction. This flexibility of application in turn led to its use in the development of improved construction methods and procedures that could not be considered before.

SINGLE YOKE ASSEMBLIES were developed for making tie-ins, installing side bends and making repairs in swamps, marshes, and other areas inaccessible to conventional land and marine equipment. Single yoke assemblies of Series H equipment are designed for dragging across marsh areas to work locations by marsh buggies. Disassembled, they can be towed down narrow water-filled ditches to work locations in swamps and assembled at the site with side booms or draglines that have been matted in.

DUAL YOKE ASSEMBLIES are designed and dimensioned for handling large diameter lines in floatation canals and open water areas. The yokes are spaced on the proper centers for obtaining breakover without damage to the concrete coating. Each assembly is symmetrical and equipped with rakes on both ends for towing and spuds on one side for positioning and holding against current, wind, and other side forces for horizontal line-up.

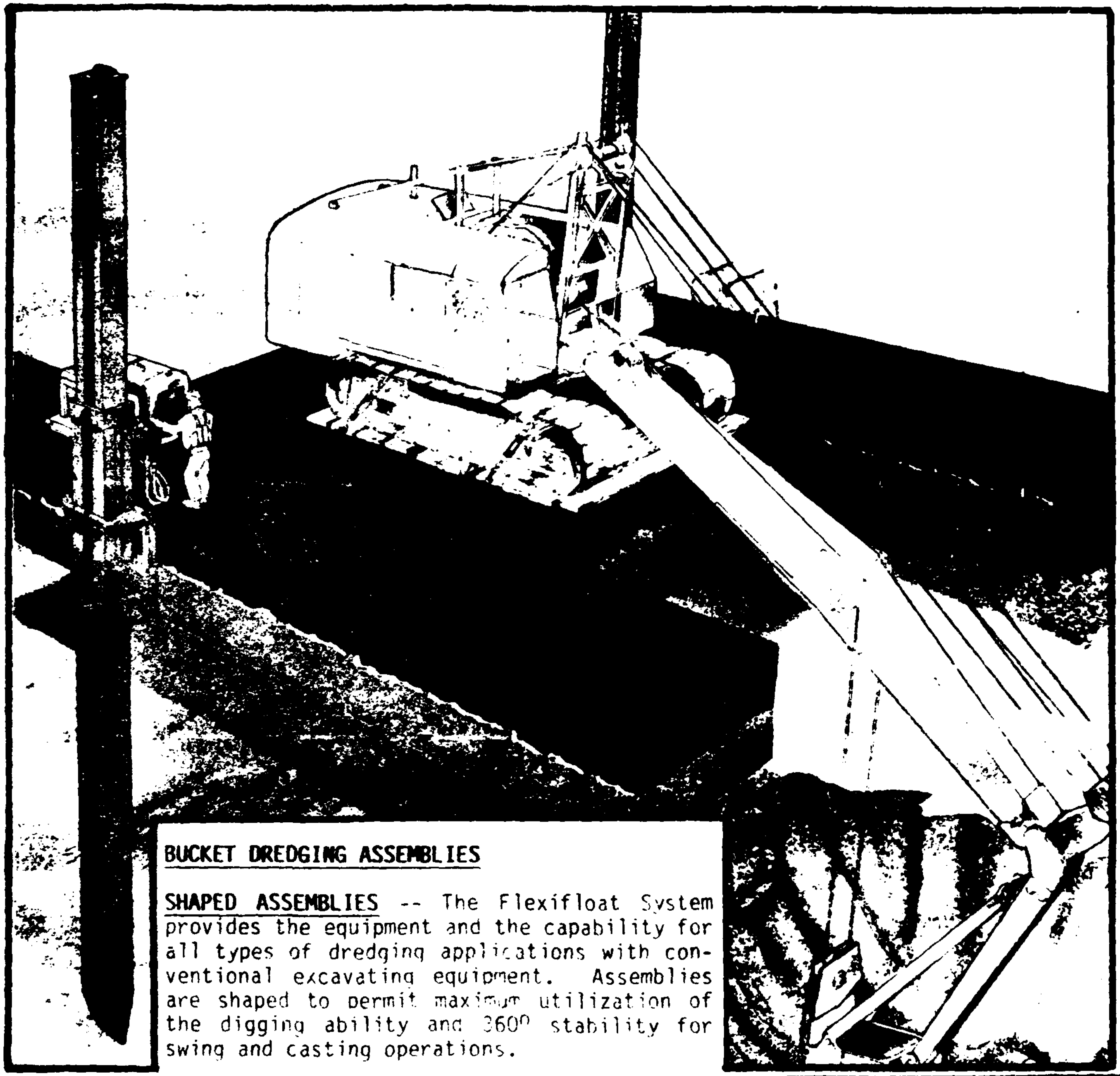
The dual lifting points keep the assemblies aligned with the pipe and proves the ability to suspend long sections of pipe above bottom for towing to remote locations. Symmetrical floatation assemblies having dual lifting points equalize the lifted load on each other to maintain a stress-free bending radius between all yokes.



DUAL YOKE ASSEMBLY

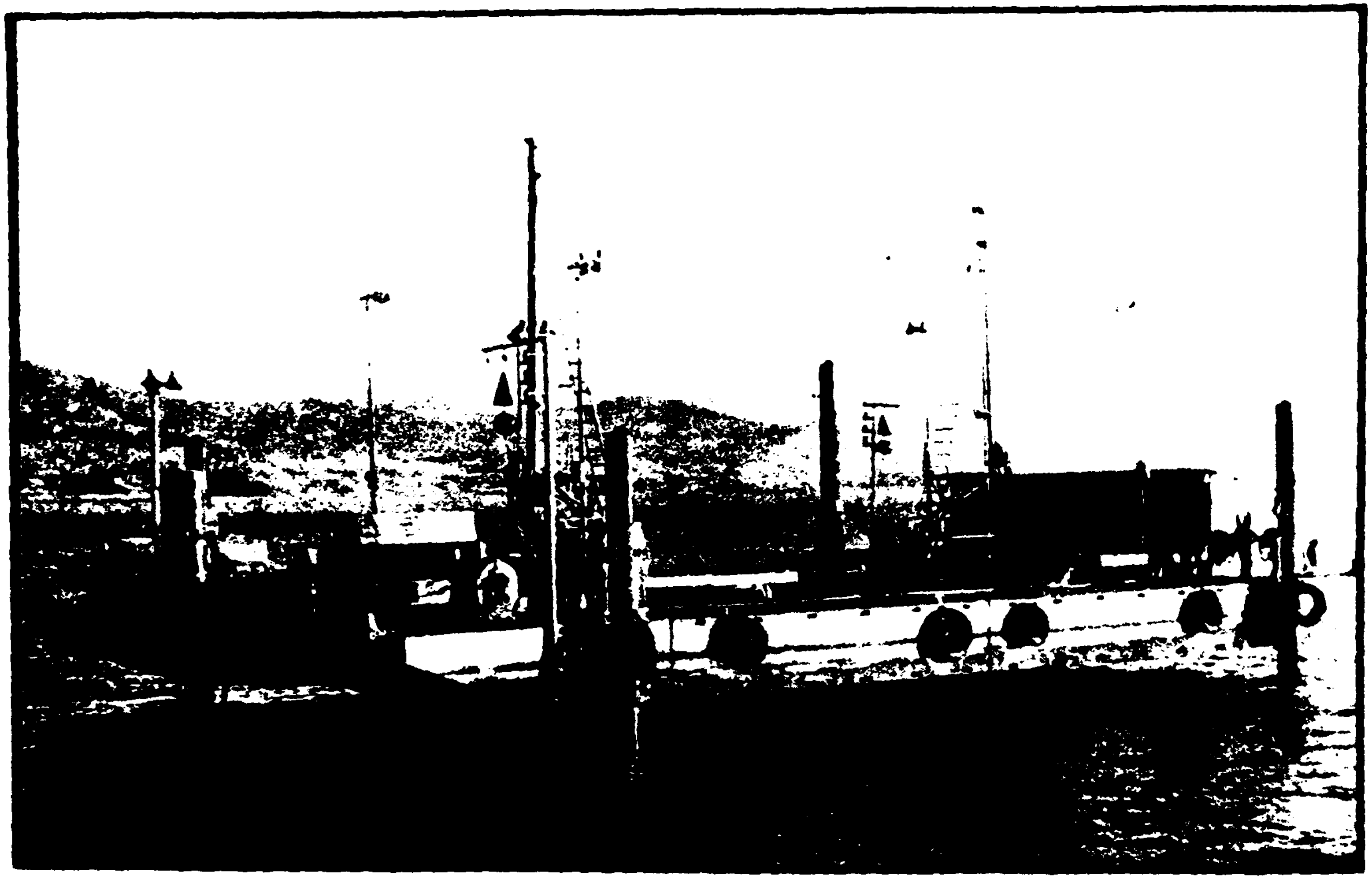
UNDERWATER MANIPULATION SYSTEMS -- Flexifloat Equipment Assemblies offer practical and economic advantages in the problems of laying subaqueous concrete lines of large diameter. They can provide floatation for working in extremely shallow waters, transport for heavy pipe sections, bottom bearing spuds for increasing load-lifting capability, central operation of winch and wireline equipment for underwater control and joining of pipe sections, and can reduce costs by improving construction methods.

UNDERWATER MANIPULATION SYSTEM



BUCKET DREDGING ASSEMBLIES

SHAPED ASSEMBLIES -- The Flexifloat System provides the equipment and the capability for all types of dredging applications with conventional excavating equipment. Assemblies are shaped to permit maximum utilization of the digging ability and 360° stability for swing and casting operations.



JACK-UP PLATFORM (SELF-ELEVATING)